THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

Quod si cui mortalium cordi et curæ sit non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant. —*Novum Organum, Præfatio.*

VOLUME THE FIFTY-NINTH.

1903.

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SOLD ALSO AT THE APARTMENTS OF THE SOCIETY.
MDCCCCIII.

List

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OF THE

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Elected February 20th, 1903.

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PROCEEDINGS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

SESSION 1902–1903.

November 5th, 1902.

Prof. Charles Lapworth, LL.D., F.R.S., President, in the Chair.

John Brooke Scrivenor, Esq., B.A., Geological Survey of England, 28 Jermyn Street, S.W., was elected a Fellow of the Society.

The List of Donations to the Library was read.

The Secretary read the following communication, transmitted by H.M. Secretary of State for the Colonies :—

'Curator, Botanic Station, St. Vincent, to Imperial Commissioner of Agriculture for the West Indies.

'Botanic Station, St. Vincent.
September 5th, 1902.

'Sir,

'Cable-communications of the eruption of the Soufrière on the 3rd and 4th instant have doubtless reached you; nevertheless I deem it my duty to forward you by this the earliest possible opportunity an official report on same :—

'Early on the afternoon of the 3rd instant telephonic communications reached me that the Soufrière was agitated, and from the Botanic Station at about 2 p.m. on that day I observed certain white and dark clouds in the direction of the Soufrière, which from their upward movements convinced me that an eruption of the Soufrière was near at hand. At 3 p.m., the hour of taking observations at the Botanic Station in the afternoon, the corrected barometrical reading was 29·947, and the attached thermometer 85° F. The wind was blowing lightly from the north-east, and the weather was bright. The only clouds were to the north, and the most conspicuous was a dark brown column, apparently over the Soufrière. At 5.30 p.m. I had a conversation with Mr. Nairn and Mr. Frederick at Montrose, and from the then appearances and sounds we were convinced that an eruption was pending. At about 8 p.m. I met in Kingstown Mr. H. Allen, Revenue Officer at Châteaubelair, who informed me that during the day he saw a lot of matter ejected over the western lip of the old crater down the Laricor or Roseau Valley to the sea. Mr. Allen and most of the residents of Châteaubelair left that place late in the afternoon for places of safety,

and in the Georgetown District (Windward) the residents moved southward. At 9.55 P.M., as seen at the Botanic Station, the eruption commenced in earnest: flashes of flame and lightning were visible over the Soufrière at intervals of 20 to 30 seconds, with frequent longer intervals. At 10.30 P.M. the corrected reading of the mercurial barometer was 30·105 and the attached thermometer 81°·5 F. From about this hour the discharges and accompanying noises increased in frequency and severity, and at 1.30 A.M. (4th) the Soufrière was in full eruption. From this hour to 2 A.M. the eruption was, in the writer's opinion, more severe than on May 7th: the explosions seeming to be louder and more continuous, and the electric discharges, owing doubtless to its being night, immeasurably grander and more awe-inspiring. The writer's house vibrated in a manner it did not do on May 7th. At 2 A.M. the corrected barometrical reading was 30·045 and the temperature 81° F., and at 3 A.M. the corrected reading was 30·035. The marvellous electric display was checked by a heavy shower from the east, and the roar was correspondingly lessened. From about 1.30 A.M. a cloud black as gunpowder was seen advancing southward from the Soufrière, and at 2.30 this cloud had assumed a circular form and was overhead of the Botanic Station. The discharges from this cloud and to northward were exceedingly numerous and severe, and the appearance generally was as though myriads of long fiery serpents were darting hither and thither, and a constant crackling noise was heard, in addition to the roar of the volcano. The chief disturbances seemed to be west of the Soufrière, in the direction of Martinique; and the writer is strongly of opinion, from observations at the time, that Mont Pelé and the Soufrière were in action together, but so far no news has come from Martinique. At 3 A.M. (4th) the discharges and roar to the west nearly subsided, and the Soufrière alone seemed in action, but more on the Windward side. From 3 to 4 A.M. the eruption gradually slackened, and at the latter hour had nearly ceased. The next morning the barometer was normal at 29·950, but the morning had a weird and gloomy appearance. No ashes or pebbles fell at the Botanic Station. No deaths are reported anywhere, and no damage to Windward, but to Leeward I learn on good authority that places partly untouched on May 7th are now very severely injured—for instance, the arrowroot-fields at Richmond Vale and Petit Bordelle and Sharpes, as well as the sugar-canes at the first-named, are extensively damaged by the thick coarse layer of material, and as far down as the Linley Estates and Cumberland extensive damage to ground-provisions and arrowroot is reported. The principal peasant-allotments are on the Linley Estates, and early to-morrow morning (6th) I am going with Mr. Osment to inspect these erstwhile thriving places. His Honour the Administrator is also visiting the Leeward District as far as Châteaubelair to-morrow. We had made arrangements for distributing some thousands of economic plants to the Leeward allottees during the coming week, but I fear that this is now out of the question, as the holders have reported that their provisions are buried deep. Last night we had one of the worst thunderstorms experienced here during the last 12 years, though the rainfall was only 0·44 inch. I enclose for your further information a copy of the 'Times' newspaper, so far the only one issued this week, and on my return from Leeward I hope to be able to give further facts.

I have etc.
(Signed) H. Powell,
Curator.

'Dr. D. Morris, C.M.G.,
Imperial Commissioner of Agriculture
for the West Indies.'

A second communication (also received through the Secretary of State for the Colonies) was read, dated Grenada, September 23rd, from Sir R. B. Llewelyn, Governor of the Windward Islands, expressing the hope that some scientific observers might be induced to go out to the West Indies and settle there for some time, in order to accumulate information as to volcanic and kindred phenomena.

The Rev. H. H. Winwood proposed, and Dr. W. T. Blanford seconded, a vote of thanks to the Colonial Department on behalf of the Society for the foregoing communications, and the vote was agreed to, *nemine contradicente*.

The following communications were read:—

1. 'The Fossil Flora of the Cumberland Coalfield, and the Palæobotanical Evidence with regard to the Age of the Beds.' By E. A. Newell Arber, Esq., M.A., F.G.S.

2. 'Some Remarks upon Mr. E. A. Newell Arber's Communication: On the Clarke Collection of Fossil Plants from New South Wales.' By Dr. F. Kurtz, Professor of Botany in the University of Córdoba, Argentine Republic. (Communicated by A. C. Seward, Esq., M.A., F.R.S., F.L.S., F.G.S.)

3. 'On a New Boring at Caythorpe (Lincolnshire).' By Henry Preston, Esq., F.G.S.

The following specimens, etc. were exhibited:—

Fossil Plants from the Cumberland Coalfield, exhibited by E. A. Newell Arber, Esq., M.A., F.G.S., in illustration of his paper.

Specimens from the Clarke Collection of Fossil Plants from New South Wales in the Woodwardian Museum, Cambridge, exhibited in illustration of Mr. Arber's reply to the paper by Prof. F. Kurtz.

Specimens from the new Boring at Caythorpe, exhibited by Henry Preston, Esq., F.G.S., in illustration of his paper.

A Portrait of Dr. Henry Woodward, F.R.S., F.G.S., presented by himself.

Geological Survey of England and Wales, 1-inch map, new series, Sheet 314. Ringwood (Drift), by C. Reid, F. J. Bennett, & E. E. L. Dixon; also old series, Sheet 64. Peterborough, Rutland, etc. (Drift), by J. W. Judd, W. H. Holloway, & S. B. J. Skertchly; both maps presented by the Director of H.M. Geological Survey.

November 19th, 1902.

Prof. Charles Lapworth, LL.D., F.R.S., President, in the Chair.

Lewis Leigh Fermor, Esq., Assistant-Superintendent, Geological Survey of India, Calcutta; and Samuel Perkes, Esq., Larnaca (Cyprus), were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'The Semna Cataract or Rapid of the Nile: a Study in River-Erosion.' By John Ball, Ph.D., A.R.S.M., F.G.S., Assoc. M.Inst.C.E.

2. 'Geological Notes on the North-West Provinces (Himalayan) of India.' By Francis J. Stephens, Esq., F.G.S., A.I.M.M.

3. 'Tin and Tourmaline.' By Donald A. MacAlister, Esq., F.G.S.

The following specimens and map were exhibited :—

Rock-Specimens and Microscope-Slides, exhibited by Dr. John Ball, A.R.S.M., F.G.S., in illustration of his paper.

Tin-Capel, consisting of a felted mass of crystals of schorl, mingled with minute crystals and small veinlets of cassiterite, from the Great Flat Lode (West Wheal Basset, Illogan, Cornwall), 140-fathom level, exhibited by J. H. Collins, Esq., F.G.S.

A Geological Map of the Dominion of Canada (western sheet), scale : 1 inch = 50 miles, 1901, presented by Prof. Robert Bell, M.D., F.R.S., F.G.S., Director of the Geological Survey of Canada.

December 3rd, 1902.

Prof. Charles Lapworth, LL.D., F.R.S., President, in the Chair.

Charles Edward Adams, Esq., B.Sc., Lecturer in Geology, Victoria College, Wellington (New Zealand); Warren Delabere Barnes, Esq., B.A., c/o Messrs. H. S. King & Co., 45 Pall Mall, S.W.; Arthur Robert Vincent Daviss, Esq., Aylestone House, Bearwood Road, Birmingham; Gilbert Henry Dutton, Esq., B.Sc., Assistant-Curator in the Public Museum of Cardiff, 122 Llandaff Road, Cardiff; Kenneth A. K. Hallowes, Esq., B.A., 12 Harvey Road, Cambridge; John Kirsopp, Jr., Esq., c/o The Cuban Mining & Development Co., Ltd., P.O. Box 714, Kohly, Havana (Cuba); James May, Esq., M.A., B.Sc., St. Mark's School, Windsor; Emil Montag, Esq., Corn-Exchange Buildings, Liverpool; Frederick Mort, Esq., M.A., B.Sc., Viewfield, Partickhill, Glasgow; William Sheldon Ridge, Esq., B.A., East Anglian School, Bury St. Edmunds; A. Trevor Roberts, Esq., B.Sc., 7 Slatey Road, Claughton, Birkenhead; William Arthur Savage, Esq., M.R.C.S., Mapumalo, Natal (South Africa); Samuel M. Tweddill, Esq., Secretary & Keeper of the Museum of the Geological Survey of the Transvaal Colony, Pretoria; and Charles Arthur Wood, Esq., M.A., 92 Cromwell Road, Montpelier, Bristol, were elected Fellows of the Society.

The List of Donations to the Library was read.

The President stated that, in accordance with the announcement published in the Report of the Council for 1901, Fellows were invited to send in to the Secretary, before January 1st, 1903, the Names of any Fellow or Fellows whom they might desire to see placed on the Council. All names sent in would be carefully considered by the Council, in making their recommendations to the Fellows at the Annual General Meeting.

The following communications were read :—

1. 'On some Well-sections in Suffolk.' By William Whitaker, Esq., B.A., F.R.S., F.G.S.

2. 'The Cellular Magnesian Limestone of Durham.' By George Abbott, Esq., M.R.C.S., F.G.S.

The following specimens, maps, etc. were exhibited :—

Specimens, Photographs, and Lantern-Slides of Cellular Magnesian Limestone from Durham, exhibited by George Abbott, Esq., M.R.C.S., F.G.S., in illustration of his paper.

Geological Survey of England and Wales, 1-inch map, new series, Sheet 123 (Solid and Drift), Stoke-upon-Trent, by G. Barrow, W. Gibson, T. I. Pocock, & C. B. Wedd. Presented by the Director of H.M. Geological Survey.

December 17th, 1902.

Prof. Charles Lapworth, LL.D., F.R.S., President, in the Chair.

C. E. Blaker, Esq., Riverside, Leam Terrace, Leamington Spa; Alexander Logie Du Toit, Esq., 26 Newton Street, Glasgow; James Gibson, Esq., Assoc.M.I.M.E., Johannesburg (Transvaal Colony); Leslie F. Harper, Esq., Sunnyside, Parramatta (New South Wales); and the Rev. Matthew Marshall, M.A., Burbage Vicarage, Buxton, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. 'Note on the Magnetite-Mines near Cogne (Graian Alps).' By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.

2. 'The Elk (*Alces machlis*, Gray) in the Thames Valley.' By Edwin Tulley Newton, Esq., F.R.S., F.G.S.

3. 'Observations on the Tiree Marble, with Notes on others from Iona.' By Ananda K. Coomáraswámy, Esq., B.Sc., F.L.S., F.G.S.

The following specimens and maps were exhibited :—

Rock-Specimens and Microscope-Slides, exhibited by Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S., in illustration of his paper; also Specimens of Glaucophane-Eclogite from near St. Marcel.

Rock-Specimens from near Cogne (Graian Alps), exhibited by the Rev. Edwin Hill, M.A., F.G.S.

Specimens of Elk-Remains from the Alluvium of the Thames, near Staines, exhibited by E. T. Newton, Esq., F.R.S., F.G.S., in illustration of his paper, and on behalf of Messrs. W. Hunter & R. E. Middleton.

Rock-Specimens, Microscope-Sections, and Lantern-Slides, exhibited by A. K. Coomáraswámy, Esq., B.Sc., F.L.S., F.G.S., in illustration of his paper.

Three new Maps presented by the Geological Commission of Switzerland:—Moutier & Belleray (Bernese Jura) by L. Rollier, and the Baden district (Aargau) by F. Mühlberg.

January 7th, 1903.

Prof. Charles Lapworth, LL.D., F.R.S., President, in the Chair.

Herbert L. Bowman, Esq., M.A., Demonstrator in Mineralogy in the University of Oxford, 13 Sheffield Gardens, London, W.; Arthur Hiorns, Jun., Esq., Carleon, Erdington; and Edward Thomas Temby, Esq., Francistown & Bulawayo, Matabeleland (South Africa), were elected Fellows of the Society.

The following Fellows, nominated by the Council, were elected Auditors of the Society's Accounts for the preceding year: Prof. E. J. Garwood and F. W. Rudler, Esq.

The List of Donations to the Library was read.

Dr. John W. Evans showed a series of rocks and fossils collected by him in the course of an expedition sent out by Sir Martin Conway to the district of Caupolican, in Northern Bolivia. He briefly described the geological structure of the country, from the high tableland near Titicaca north-eastward across the Cordillera Real, and other parallel mountain-chains, to the Amazonian plain.

He also exhibited specimens of crystalline rocks from the cataracts of the Rio Madeira, where the river makes its way through the broad outcrop of ancient rocks that traverses the centre of Brazil in a direction similar to that of the Andes in the same latitudes.

The following communication was read:—

'On the Discovery of an Ossiferous Cavern of Pliocene Age at Dove Holes, Buxton (Derbyshire).' By William Boyd Dawkins, M.A., D.Sc., F.R.S., F.S.A., F.G.S., Professor of Geology in Owens College, Victoria University (Manchester).

In addition to the specimens mentioned above, the following were exhibited:—

Bones and Teeth of *Mastodon*, *Rhinoceros*, *Equus*, & *Machairodus* from the Pliocene Cave, Dove Holes (Derbyshire), exhibited by Prof. W. Boyd Dawkins, M.A., D.Sc., F.R.S., F.S.A., F.G.S., in illustration of his paper.

January 21st, 1903.

Prof. Charles Lapworth, LL.D., F.R.S., President, in the Chair.

Frederick Lionel Daniels, Esq., Fern Cottage, Lighthill, Stroud (Gloucestershire); George Cecil Gough, Esq., Lecturer in Geology at Queen's College, Belfast, 109 Wellesley Avenue, Belfast; and Bertram Montgomery Oxley-Oxland, Esq., Delamore Hall, Hillcrest, Natal (South Africa), were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'The Figure of the Earth.' By William Johnson Sollas, M.A., D.Sc., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford.

2. 'The Sedimentary Deposits of Southern Rhodesia.' By Arthur John Charles Molyneux, Esq., F.G.S.

The following specimens, etc. were exhibited:—

A Globe and Lantern-Slides, exhibited by Prof. W. J. Sollas, M.A., D.Sc., LL.D., F.R.S., F.G.S., in illustration of his paper.

Specimens with fossil remains of Fishes, Plants, and Mollusca, from the coal-bearing beds (Permo-Carboniferous) of Southern Rhodesia, exhibited by A. J. C. Molyneux, Esq., F.G.S., in illustration of his paper.

Geological Map of Spain, by Amalio Maestre, $\frac{1}{2,000,000}$, Madrid, 1863, presented by James N. Shoolbred, Esq., C.E.

February 4th, 1903.

Prof. Charles Lapworth, LL.D., F.R.S., President, in the Chair.

Walter Baldwin, Esq., 218 Yorkshire Street, Rochdale; and Thomas Nicholas Leslie, Esq., Vereeniging (Transvaal Colony), were elected Fellows of the Society.

The List of Donations to the Library was read.

Mr. H. E. H. Smedley exhibited and commented on wax-models, prepared by himself, of the following Fossil Seeds:—

(1) *Stephanospermum akenioides*, a Palæozoic seed from the Permo-Carboniferous formation of St. Étienne. Models of this

seed represent longitudinal and transverse sections through the pollen-chamber and also through the prothallus.

(2) The fossil seed *Lagenostoma*, from the Coal-Measures of Lancashire, is modelled in a similar manner, and shows a very interesting structure, especially in the region of the pollen-chamber.

(3) A model of *Pachytesta*, a large fossil seed of Cycadean type, was exhibited, and also models of the seeds of the recent Gymnosperms, *Zamia* and *Torreya nucifera*, showing some strong points of resemblance.

The models of the fossil seeds show all the additional features recently observed by Prof. F. W. Oliver in his researches on these fossils, to whom Mr. Smedley expressed his indebtedness for the help and suggestions that had made it possible for him to prepare the models exhibited.

The following communications were read:—

1. 'The Granite and Greisen of Cligga Head (Western Cornwall). By John Brooke Scrivenor, Esq., M.A., F.G.S.[1]

2. 'Notes on the Geology of Patagonia.' By John Brooke Scrivenor, Esq., M.A., F.G.S.

3. 'On a Fossiliferous Band at the Top of the Lower Greensand near Leighton Buzzard (Bedfordshire).' By George William Lamplugh, Esq., F.G.S., and John Francis Walker, Esq., M.A., F.L.S., F.G.S.

In addition to the specimens described above, the following were exhibited:—

Rock-Specimens, Microscope-Sections, and Lantern-Slides of Granite and Greisen from Cligga Head, exhibited by J. B. Scrivenor, Esq., M.A., F.G.S., in illustration of his paper on that district.

Microscope-Sections of Santa Cruz Rocks and Lantern-Slides, exhibited by J. B. Scrivenor, Esq., M.A., F.G.S., in illustration of his paper on the Geology of Patagonia.

Fossils from the Band at the Top of the Lower Greensand, near Leighton Buzzard, exhibited by G. W. Lamplugh, Esq., F.G.S., and J. F. Walker, Esq., M.A., F.L.S., F.G.S., in illustration of their paper.

Colour-printed copies of n.s. 1-inch Geological Survey Maps, Nos. 232, 248, & 249, presented by the Director of H.M. Geological Survey.

Eighteen Platinotype Photographs (cabinet size) of Fellows of the Society, presented by Messrs. Maull & Fox.

[1] Communicated by permission of the Director of H.M. Geological Survey.

ANNUAL GENERAL MEETING,

February 20th, 1903.

Prof. CHARLES LAPWORTH, LL.D., F.R.S., President, in the Chair.

REPORT OF THE COUNCIL FOR 1902.

THE Society continues to be in a generally flourishing condition. The Number of Fellows has undergone but little change: during the past year 48 Fellows were elected (4 less than in 1901, and 11 less than in 1900), of whom 30 paid their Admission Fees before the end of the year. Moreover, 18 Fellows, who had been elected in the previous year, paid their Admission Fees in 1902, the total accession of new Fellows during the past twelve months amounting therefore to 48.

Deducting from this a loss of 42 Fellows (20 by death, 11 by resignation, and 11 by removal from the List, under Bye-Laws, Sect. VI, Art. 5), it will be seen that there is an increase in the number of Fellows of 6 (as compared with a decrease of 4 in 1901, and 10 in 1900).

This brings the total number of Fellows up to 1258, made up as follows:—Compounders 289, Contributing Fellows 930, Non-Contributing Fellows 39.

Turning now to the Lists of Foreign Members and Foreign Correspondents, it is a matter for congratulation that there has been no vacancy during the year among the Foreign Members. Two deaths, however, have to be recorded among the Foreign Correspondents (namely, Prof. A. Hyatt and Major J. W. Powell), making with 2 places remaining unfilled at the end of 1901 4 vacancies. Of these 3 have been filled by the election of Prof. T. C. Chamberlin, Dr. Th. Thoroddsen, and Prof. S. W. Williston, leaving one place still vacant.

With regard to the Income and Expenditure of the Society during the past year, the figures set forth in detail in the Balance-Sheet may be summarized as follows:—

The total Receipts, including the Balance of £403 12*s.* 3*d.* brought forward from the previous year, amounted to £3439 16*s.* 3*d.*, being £81 more than the estimated Income.

The total Expenditure during 1902 (exclusive of the sum of £250 invested in Natal Government 3 per Cent. Stock) amounted to £3128 8*s.* 7*d.*, being £73 4*s.* 7*d.* more than the estimated Expenditure for that year.

The Estimates laid before the Fellows at the last Annual General Meeting were exceeded chiefly in the case of the Library (£66 1*s.* 5*d.*), the List of Geological Literature (£17 10*s.* 0*d.*), and the Quarterly Journal (£69 4*s.* 0*d.*). On the other hand, the Expenditure incurred

in connexion with the Museum Catalogue will fall within the accounts of the present year.

The Council have to announce the completion of Vol. LVIII and the commencement of Vol. LIX of the Society's Quarterly Journal.

The Catalogue of type- and other important specimens in the Society's Museum, based on Mr. Sherborn's manuscript catalogue, edited and prepared for publication by the Rev. J. F. Blake, has now been issued. The Council are confident that the Fellows will concur with them in the opinion that the Society is much indebted to Prof. Blake for so generously placing his time and services at the disposal of the Society in bringing out this most valuable work. Both he and Mr. Sherborn are to be congratulated on the fruit of their labours being at length made accessible to the public. The information embodied in the Catalogue will facilitate the discussion of certain suggestions which have been made relative to the future of the collections in the Society's Museum.

The manuscript Card-Catalogue of the Library (to which reference was made in the previous Annual Report) has been commenced by Mr. C. Davies Sherborn, F.G.S., and considerable progress has been made with it.

Mr. Sherborn has also undertaken to continue during the current year the preparation and editing of the catalogue-slips for the International Catalogue of Scientific Literature.

On the occasion of the Coronation of Their Majesties, The King and Queen, the Society joined with the other Scientific Societies having apartments in Burlington House in a scheme for the decoration and illumination of the front of the building, in honour of that auspicious event and of the happy restoration of His Majesty to health.

The Society shared in the worldwide sympathy felt for the sufferers from the calamitous eruptions in St. Vincent and Martinique; and the President and Council, on behalf of themselves and the Fellows, forwarded letters to the Secretary of State for the Colonies and to the French Minister of the Colonies, giving due expression to this sympathy. These letters were courteously acknowledged.

The following Awards of Medals and Funds have been made by the Council:—

The Wollaston Medal is awarded to Geheimrath Prof. Dr. Heinrich Rosenbusch, in recognition of the value of his researches concerning the Mineral Structure of the Earth, and more particularly of his investigations of the Microscopic Structure and Mineralogical Composition of the Igneous Rocks and Crystalline Schists.

The Murchison Medal, together with a sum of Fifteen Guineas from the Murchison Geological Fund, is awarded to Dr. Charles Callaway, in recognition of his valuable contributions to our knowledge of the Cambrian and Archæan rocks of Shropshire, the Malverns, and the Scottish Highlands.

The Lyell Medal, together with a sum of Twenty-Five Pounds from the Lyell Geological Fund, is awarded to Mr. Frederick William Rudler, in recognition of his important services to Geological Science

during the long period of his Curatorship of the Museum of Practical Geology in Jermyn Street.

The Bigsby Medal is awarded to Dr. Henry M. Ami, as an acknowledgment of his eminent services to Geology, and especially in the department of Palæontology, in the Dominion of Canada.

The first Prestwich Medal is awarded to Lord Avebury, as an acknowledgment of the work which he has done for the advancement of the Science of Geology, particularly in regard to the evidence of the Antiquity of Man, and in his works on the Scenery of Switzerland and of England.

The Balance of the Proceeds of the Wollaston Donation Fund is awarded to Mr. L. L. Belinfante, in recognition of his services to Geology, and especially of his Index to the first Fifty Volumes of the Quarterly Journal, and as an appreciation of his conscientious services as Editor of the Journal and Assistant Secretary.

The Balance of the Proceeds of the Murchison Geological Fund is awarded to Mrs. Elizabeth Gray, as an acknowledgment of her services to Palæontology, particularly in Scotland, and to encourage her in further work.

A moiety of the Balance of the Proceeds of the Lyell Geological Fund is awarded to Mr. George Edward Dibley, in recognition of his valuable researches among the fossils of the Chalk of the South of England, and to assist him in further work.

The other moiety of the Balance of the Proceeds of the Lyell Geological Fund is awarded to Mr. Sydney S. Buckman, as an acknowledgment of his contribution to our knowledge of the Cephalopoda and Brachiopoda, and the Stratigraphy of the Oolites, and to assist him in further research.

Report of the Library and Museum Committee for 1902.

The Additions made to the Library during the past twelve months fully maintain, both in number and interest, the standard of former years.

During 1902 the Library received by donation 169 Volumes of separately published Works, 310 Pamphlets and detached Parts of Works, 188 Volumes and 40 detached Parts of Serial Publications, and 18 Volumes of Newspapers.

The total number of accessions to the Library by Donation is thus seen to amount to 375 Volumes, 310 Pamphlets, and 40 detached Parts.

The number of Maps, which have been presented by various Donors, is again very considerable. No less than 182 Sheets of Maps were received, 67 of which came from the Ordnance Survey Department.

Although the task of selection from among the numerous Donations mentioned in the foregoing paragraphs is necessarily difficult, your Committee may perhaps be allowed to direct special attention to the following:—Mr. P. McConnell's 'Elements of Agricultural Geology'; Mr. R. W. Dron's 'Coalfields of Scotland'; Mr. Jukes-

Browne's 'Student's Handbook of Stratigraphical Geology'; the second part of the new edition of Prof. Kayser's 'Lehrbuch der Geologie'; M. E. Coste's memoir on the Geology of the Loire Coalfield; the Royal Society's twelfth or supplementary Volume of the Catalogue of Scientific Papers (1880–83); the Geological Survey Memoirs on the South Wales Coalfield (part 3), and on the districts of Stoke-upon-Trent, Ringwood, Southampton, and Exeter; also the Memoir on the Water-Supply of Berkshire, and those on the Geology of Eastern Fife and Lower Strathspey. Moreover, numerous publications were received from the Geological Survey departments of Canada, Cape Colony, Natal, Mysore, Queensland, the United States, Denmark, Norway, Sweden, Russia, Switzerland, Spain, Egypt, and Japan. Herr H. Hauswaldt presented his fine work on the 'Interference-Phenomena of Doubly-refracting Crystals in Convergent Polarized Light.' Mr. W. F. Wilkinson, F.G.S., gave to the Library 13 volumes of various scarce works.

In addition to the Ordnance Survey maps mentioned in a preceding paragraph, 4 Sheets of maps were received from the Geological Survey of Great Britain; 24 Sheets from the Geological Survey of Sweden; 3 Sheets from that of Switzerland; and one each from those of Russia and Finland. Special interest attaches to the Geological Map of British Guiana, in 4 Sheets; to Dr. Thoroddsen's Geological Map of Iceland; to the 7 new Sheets of the International Geological Map of Europe; and to the 16 topographical maps of the long-disputed Argentine-Chilian boundary, accompanied as they were by three large volumes containing a great number of plates illustrating the structure and scenery of the higher Andes.

The Imperial Commissioner for Agriculture in the West Indies, Dr. D. Morris, C.M.G., presented eight photographs illustrative of the disastrous eruptions in St. Vincent and Martinique; and Dr. Henry Woodward presented a framed portrait of himself, which has been added to the Society's collection of Portraits of Eminent Geologists.

The Books, Maps, and Photographs enumerated above were the gift of 176 Personal Donors; 122 Government Departments and other Public Bodies; and 165 Societies and Editors of Periodicals.

The Purchases made on the recommendation of the standing Library Committee, included 52 Volumes and 38 Parts of separately published Works; 22 Volumes and 11 Parts of Works published serially; and 13 (separate) Sheets of Maps.

A set of the first series of lantern-slides issued by the Geological Photographs Committee of the British Association was subscribed for, and is now deposited in the Library.

The total Expenditure in connexion with the Library during the year 1902 was as follows:—

	£	s.	d.
Books, Periodicals, etc. purchased..........	91	15	3
Binding of Books and Mounting of Maps....	174	6	2
Total	£266	1	5

or £66 1*s.* 5*d.* more than the sum set apart for these purposes in the Estimates.[1] Your Committee feel assured, however, that the Fellows will not grudge any Expenditure that appears necessary for the maintenance and improvement of the Library.

Museum.

Two microscope-sections of altered siliceous sinter from Builth (Brecknockshire) were presented by Mr. Frank Rutley; samples of volcanic ash collected in Barbados on May 7th–8th were presented by Dr. D. Morris, C.M.G.; and samples of volcanic ash collected at St. Pierre (Martinique) on May 11th by Mr. Arthur D. Whatman, were presented by his father, Mr. George D. Whatman.

For the purpose of study and comparison the Collections were examined on 22 different occasions during the year, the contents of about 160 drawers being thus examined.

The newly published Museum Catalogue and the Library Card-Catalogue in progress are referred to more fully in the Council's Annual Report.

The appended Lists contain the Names of Government Departments, Public Bodies, Societies, Editors, and Personal Donors, from whom Donations to the Library have been received during the year under review:—

I. Government Departments and other Public Bodies.

American Museum of Natural History. New York.
Argentine Government.
Athens.—Observatoire National d'Athènes.
Australian Museum. Sydney (N.S.W.).
Austria.—Kaiserlich-königliche Geologische Reichsanstalt. Vienna.
——. Kaiserlich-königliches Naturhistorisches Hofmuseum. Vienna.
Bavaria.—Königliches Bayerisches Oberbergamt. Munich.
Belgium.—Académie Royale des Sciences, des Lettres & des Beaux-Arts de Belgique. Brussels.
——. Musée Royal d'Histoire Naturelle. Brussels.
Berlin.—Königliche Preussische Akademie der Wissenschaften.
Birmingham, University of.
Bohemia.—Royal Museum of Natural History. Prague.
British Columbia.—Department of Mines, Victoria (B.C.).
—— ——. Bureau of Provincial Information, Victoria (B.C.).
British Guiana.—Department of Mines. Georgetown.
British South Africa Company. London.
Buenos Aires.—Museo Nacional.
California University. Berkeley (Cal.).
Cambridge (Mass.).—Museum of Comparative Zoology, Harvard College.
Canada.—Geological & Natural History Survey. Ottawa.
Cape Colony.—Department of Agriculture. Geological Commission. Cape Town.
Chicago.—'Field' Columbian Museum.
Christiania, University of.
Denmark.—Commission for Ledelsen af de Geologiske og Geographiske Undersögelser i Grönland. Copenhagen.

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[1] About £43 0*s.* 0*d.* was paid early in 1902, in respect of binding work completed in 1901.

Denmark.—Danmarks Geologiske Undersögelse. Copenhagen.
——. Kongelige Danske Videnskabernes Selskab. Copenhagen.
Dublin.—Royal Irish Academy.
Egypt.—Geological Survey. Cairo.
Finland.—Finlands Geologiska Undersökning. Helsingfors.
France.—Dépôt de la Marine. Paris.
——. Ministère des Travaux Publics. Paris.
——. Muséum d'Histoire Naturelle. Paris.
Germany.—Kaiserliche Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher. Halle a. d. Saale.
Great Britain.—Army Medical Department. London.
——. British Museum (Natural History). London.
——. Colonial Office. London.
——. Geological Survey. London.
——. Home Office. London.
——. India Office. London.
——. Ordnance Survey. Southampton.
Holland.—Departement van Kolonien. The Hague.
Hull.—Municipal Museum.
Hungary.—Königliche Ungarische Geologische Anstalt (Magyar Földtani Tarsulat). Budapest.
India.—Geological Survey. Calcutta.
——. Surveyor General's Office. Calcutta.
Iowa Geological Survey. Des Moines (Iowa).
Italy.—Reale Comitato Geologico. Rome.
Japan.—Earthquake Investigation Committee. Tokio.
——. Geological Survey. Tokio.
Jassy, University of.
Kingston (Canada).—Queen's College.
Lima. Escuela de Ingenieros.
London.—City of London College.
——. Royal College of Surgeons.
——. University College.
Louisiana Exposition. St. Louis (Mo.).
Maryland Geological Survey. Baltimore (Md.).
Mexico.—Instituto Geologico. Mexico City.
Michigan College of Mines. Houghton (Mich.).
Milan.—Reale Istituto Lombardo di Scienze & Lettere.
Missouri Geological Survey. Jefferson City (Mo.).
Montana University. Missoula (Mont.).
Munich.—Königliche Bayerische Akademie der Wissenschaften.
Mysore Geological Department. Bangalore.
Nancy.—Académie de Stanislas.
Newfoundland.—Geological Survey. St. John (N.F.).
New Jersey Geological Survey. Trenton (N.J.).
New South Wales.—Agent-General for, London.
——. Department of Lands. Sydney.
——. Department of Mines & Agriculture. Sydney.
——. Geological Survey. Sydney.
New York Museum. Albany (N.Y.).
New Zealand.—Department of Mines. Wellington.
Norway.—Geologiske Undersögelse. Christiania.
——. Meteorological Department. Christiania.
Nova Scotia.—Department of Mines. Halifax (N.S.).
Padua.—Reale Accademia di Scienze, Lettere & Arti.
Paris.—Académie des Sciences.
Perak Government. Taiping.
Peru.—Ministerio de Fomento. Lima.
Pisa, Royal University of.
Portugal.—Commissão dos Trabalhos geologicos. Lisbon.
Prussia.—Ministerium für Handel & Gewerbe. Berlin.
——. Königliche Preussische Geologische Landesanstalt. Berlin.
Queensland.—Agent-General for, London.
——. Department of Mines. Brisbane.
——. Geological Survey. Brisbane.
Redruth School of Mines.
Rome.—Reale Accademia dei Lincei.
Russia.—Comité Géologique. St. Petersburg.
——. Section Géologique du Cabinet de S.M. l'Empereur. St. Petersburg.

Saxony.—Geological Survey. Leipzig.
South Australia.—Agent-General for, London.
——. Government Geologist. Adelaide.
South Wales & Monmouthshire University College. Cardiff.
Spain.—Comision del Mapa Geológico. Madrid.
St. Petersburg.—Académie Impériale des Sciences.
Stockholm.—Kongliga Svenska Vetenskaps Akademi.
Sweden.—Sveriges Geologiska Undersökning. Stockholm.
Switzerland.—Geologische Kommission der Schweiz. Bern.
Tasmania.—Secretary for Mines. Hobart.
Tiflis.—Kaukasisches Museum.
Tokio.—Imperial University.
——. College of Science.
Transvaal Geological Survey. Pretoria.
Turin.—Reale Accademia delle Scienze.
United States Geological Survey. Washington (D.C.).
——. Department of Agriculture. Washington (D.C.).
——. National Museum. Washington (D.C.).
Upsala, University of.
—— ——. Mineralogical & Geological Institute.
Victoria (Austr.).—Agent-General for, London.
—— (——). Department of Mines, Melbourne.
Vienna.—Kaiserliche Akademie der Wissenschaften.
Washington (U.S.A.).—Geological Survey. Olympia (Wash.).
—— (D.C.).—Smithsonian Institution.
Western Australia.—Agent-General for, London.
——. Department of Lands. Perth.
——. Department of Mines. Perth.
——. Geological Survey. Perth.
——. Victoria Public Library. Perth.
Wisconsin.—Geological & Natural History Survey. Madison (Wisc.).

II. Societies and Editors.

Adelaide.—Royal Society of South Australia.
Alnwick.—Berwickshire Naturalists' Club.
Auckland (N.Z.).—New Zealand Institute of Mining Engineers.
Bahia.—Instituto Geographico & Historico.
Barnsley.—Midland Institute of Mining, Civil, & Mechanical Engineers.
Basel.—Naturforschende Gesellschaft.
Bath.—Natural History & Antiquarian Field Club.
Belfast.—Natural History & Philosophical Society.
Belgrade.—Servian Geological Society.
Berlin.—Deutsche Geologische Gesellschaft.
——. Gesellschaft Naturforschender Freunde.
——. 'Zeitschrift für Praktische Geologie.'
Bern.—Schweizerische Naturforschende Gesellschaft.
Bombay Branch of the Royal Asiatic Society.
Bordeaux.—Société Linnéenne.
Boston Society of Natural History.
Boston (Mass.).—American Academy of Arts & Sciences.
Brunswick.—Verein für Naturwissenschaft zu Braunschweig.
Brussels.—Société Belge de Géologie, de Paléontologie & d'Hydrologie.
——. Société Malacologique de Belgique.
Budapest.—Földtani Közlöny (Geological Magazine).
Buenos Aires.—Instituto Geografico Argentino.
——. Sociedad Científica Argentina.
Calcutta.—'Indian Engineering.'
——. Asiatic Society of Bengal.
Cambridge.—Philosophical Society.
Cape Town.—South African Philosophical Society.
Cardiff.—South Wales Institute of Engineers.
Chicago.—Academy of Sciences.
——. 'Journal of Geology.'
Christiania.—'Nyt Magazin for Naturvidenskaberne.'
Cincinnati Society of Natural History.

Colombo.—Ceylon Branch of the Royal Asiatic Society.
Colorado Springs.—'Colorado College Studies.'
Copenhagen.—Dansk Geologisk Forening.
Córdoba (Argentine Republic).—Academia Nacional de Ciencias.
Cracow.—Académie des Sciences (Akademia Umiejetnosci).
Croydon Microscopical & Natural History Society.
Darmstadt.—Verein für Erdkunde.
Davenport (Iowa).—Academy of Natural Sciences.
Douglas.—Isle of Man Natural History & Antiquarian Society.
Dresden.—Naturwissenschaftliche Gesellschaft.
——. Verein für Erdkunde.
Edinburgh.—Royal Physical Society.
——. Royal Scottish Geographical Society.
——. Royal Society.
Ekaterinburg.—Société Ouralienne d'Amateurs des Sciences Naturelles.
Frankfurt am Main.—Senckenbergische Naturforschende Gesellschaft.
Freiburg im Breisgau.—Naturforschende Gesellschaft.
Geneva.—Société Physique & d'Histoire Naturelle.
Giessen.—Oberhessische Gesellschaft für Natur- & Heilkunde.
Glasgow.—International Engineering Congress.
Gratz.—Naturwissenschaftlicher Verein für Steiermark.
Haarlem.—Société Hollandaise des Sciences.
Halifax (N.S.).—Nova Scotian Institute of Science.
Hamilton (Canada).—Hamilton Association.
Hampstead Scientific Society.
Helsingfors.—Geografiska Förening i Finland.
——. Meddelanden från Industristyrelsen i Finland.
Hermannstadt.—Siebenbürgischer Verein für Naturwissenschaften.
Hertford.—Hertfordshire Natural History Society.
Hobart.—Royal Society of Tasmania.
Hull Geological Society.
Indianapolis.—Indiana Academy of Science.
Kiev.—Société des Naturalistes.
Lausanne.—Société Vaudoise des Sciences Naturelles.
Lawrence.—'Kansas University Bulletin.'
Leeds.—Yorkshire Geological & Polytechnic Society.
Leicester Literary & Philosophical Society.
Leipzig.—'Zeitschrift für Krystallographie & Mineralogie.'
Le Puy.—Société d'Agriculture, Science, Art & Commerce.
Liége.—Société Géologique de Belgique.
——. Société Royale des Sciences.
Lille.—Société Géologique du Nord.
Lima.—'Revista de Ciencias.'
——. Sociedad geografica.
Lisbon.—Sociedade de Geographia.
Liverpool Literary & Philosophical Society.
London.—'Academy.'
——. 'Athenæum.'
——. British Association for the Advancement of Science.
——. British Association of Waterworks Engineers.
——. 'Chemical News.'
——. Chemical Society.
——. 'Colliery Guardian.'
——. East India Association.
——. 'Geological Magazine.'
——. Geologists' Association.
——. Institution of Civil Engineers.
——. Institution of Mining & Metallurgy.
——. Iron & Steel Institute.
——. 'Iron & Steel Trades' Journal.'
——. 'Knowledge.'
——. Linnean Society.
——. 'London, Edinburgh, & Dublin Philosophical Magazine.'
——. Mineralogical Society.
——. 'Nature.'
——. Palæontographical Society.
——. 'Quarry.'
——. Royal Agricultural Society.
——. Royal Geographical Society.

London.—Royal Institution.
——. Royal Meteorological Society.
——. Royal Microscopical Society.
——. Royal Photographic Society of Great Britain.
——. Royal Society.
——. Society of Arts.
——. Society of Biblical Archæology.
——. South-Eastern Naturalist (S.E. Union of Scientific Societies).
——. Victoria Institute.
——. 'Water.'
——. Zoological Society.
Manchester Geological Society.
——. Literary & Philosophical Society.
Melbourne.—Australasian Institute of Mining Engineers.
——. Royal Society of Victoria.
Mexico.—Sociedad Científica 'Antonio Alzate.'
Montreal.—Natural History Society.
Moscow.—Société Impériale des Naturalistes.
New Haven (Conn.).—'American Journal of Science.'
New York.—Academy of Sciences.
——. American Institute of Mining Engineers.
Newcastle-upon-Tyne.—Institution of Mining Engineers.
——. North of England Institute of Mining & Mechanical Engineers.
Northampton.—Northamptonshire Natural History Society.
Nürnberg.—Naturhistorische Gesellschaft.
Paris.—Société Française de Minéralogie.
——. Société Géologique de France.
——. 'Spelunca.'
Penzance.—Royal Geological Society of Cornwall.
Perth.—Perthshire Society of Natural Science.
Philadelphia.—Academy of Natural Sciences.
——. American Philosophical Society.
Pisa.—Società Toscana di Scienze Naturali.
Plymouth.—Devonshire Association for the Advancement of Science.
Portland (Me.).—Society of Natural History.
Rennes.—Société Scientifique & Médicale de l'Ouest.
Rochester (N.Y.).—Geological Society of America.
Rome.—Società Geologica Italiana.
Rugby School Natural History Society.
Santiago de Chile.—Deutscher Wissenschaftlicher Verein.
——. Sociedad Nacional de Mineria.
——. Société Scientifique du Chili.
Scranton (Pa.).—'Mines & Minerals.'
St. Petersburg.—Russische Kaiserliche Mineralogische Gesellschaft.
Stockholm.—Geologiska Förening.
Stuttgart.—'Centralblatt für Mineralogie, Geologie & Paläontologie.'
——. 'Neues Jahrbuch für Mineralogie, Geologie & Paläontologie.'
——. Verein für Vaterländische Naturkunde in Württemberg.
——. 'Zeitschrift für Naturwissenschaften.'
Sydney (N.S.W.).—Australasian Association for the Advancement of Science.
——. Linnean Society of New South Wales.
——. Royal Society of New South Wales.
Toronto.—Canadian Institute.
——. Royal Society of Canada.
Toulouse.—Société d'Histoire Naturelle.
Truro.—Royal Institution of Cornwall.
Vienna.—'Berg- & Hüttenmännisches Jahrbuch.'
——. Kaiserlich-Königliche Zoologisch-Botanische Gesellschaft.
Washington (D.C.).—Academy of Sciences.
——. Biological Society.
——. Philosophical Society.
Wellington (N.Z.).—New Zealand Institute.
York.—Yorkshire Philosophical Society.
Zurich.—Société helvétique des Sciences Naturelles.

III. Personal Donors.

Ackroyd, A.
Allen, H. A.
Ameghino, F.
Anderson, T.
Anderson, W.

Ball, J.
Balta, J.
Barron, T.
Bather, F. A.
Baticle, A.
Bauerman, H.
Beadnell, H. Y. L.
Beecher, C. E.
Blake, W. P.
Bodenbender, G.
Bonney, T. G.
Boule, M.
Branner, J. C.
Brœgger, W. C.
Brough, B. H.
Brown, M. W.
Brown, H. Y. L.
Brun, A.
Buckman, S. S.
Bullen, R. A.
Burckhardt, C.
Burckhardt, F.

Cadell, H. M.
Calderon, S.
Card, G. W.
Choffat, P.
Clark, W. B.
Claxton, E. G.
Cole, G. A. J.
Collins, J. H.
Conwentz, H.
Coomáraswámy, A. K.
Cornish, V.
Credner, H.
Crick, G. C.
Cvijič, J.

Dale, E.
Dawson, C.
Dieseldorff, A.
Dollot, A.
Donald, J.
Dron, R. W.
Dunn, W. S.
Dunstan, B.

Edwards, W.
Emmons, S. F.
Espin, T. E.

Flett, J. S.
Foord, A. H.
Ford, W. E.
Foster, C. Le N.
Francis, W.

Garwood, E. J.
Gaudry, A.
Gilpin, jun., E.
Greenwell, A.
Griffiths, P.
Groom, T. T.
Grundy, J.

Hamberg, A.
Harlé, E.
Harrison, J. B.
Harrison, W. J.
Hatch, F. H.
Hauswaldt, H.
Hayden, H. H.
Hillebrand, W. F.
Hillmann, G.
Hind, W.
Holland, R.
Hopkinson, J.
Hovey, E. O.
Howley, J. P.
Hull, E.
Hume, W. F.
Hutton, F. W.

Issel, A.

Jack, R. L.
Jentzsch, A.
Jervis, W. P.
Jones, T. R.
Jukes-Browne, A. J.

Kayser, E.
Kilian, W.
Koch, A.
Koken, E.
Kreichgauer, D.
Kümmel, H. B.
Kurtz, F.

Lambe, L. M.
Lapparent, A. de.
Leclère, A.
Lee, J.
Letts, R. F.
Liebisch, T.
Lœwinson-Lessing, F.
Longe, F. D.
Loriol, P. de.
Lovisato, D.
Lowe, H. J.
Lucas, A.
Lyman, B. S.

McConnell, P.
McKay, A.
Macpherson, J.
McPherson, W.
Madsen, V.
Marbut, C. F.
Matley, C. A.
Meinardus, W.
Meli, R.
Mendenhall, W. C.
Merrill, G. P.
Metcalfe, A. T.
Mohn, H.
Mojsisovics, E. von.
Monckton, H. W.
Moreno, F. P.
Mourlon, M.
Mühlberg, F.

Nares, Sir George.
Nathorst, A. G.
Newton, E. T.
Newton, R. B.
Nordmann, V.

Oldham, R. D.
Omboni, G.

Pace, S.
Pavlov, A. P.
Peacocks, E. A. W.
Penfield, S. L.
Preller, C. S. Du R.

Rabot, C.
Ramond, G.
Rands, W. H.
Raulin, V.
Reade, T. M.
Reid, C.
Reusch, H.
Robertson, W. F.
Rosenbusch, H.
Roth, S.
Rutley, F.
Rutot, A.

Sacco, F.
Sacco, M.
Sauvage, H. E.
Sawyer, A. R.
Seward, A. C.
Sheppard, T.
Spencer, J. W.
Steinmann, G.
Stobbs, J. T.

Tassin, W.
Thompson, B.
Thoroddsen, Th.
Twelvetrees, W. H.

Walford, E. A.
Warren, S. H.
Watts, W. W.
Wellburn, E. D.
Wells, H. L.
Whitaker, W.
Whitfield, R. P.
Wilkinson, W. F.
Woods, H.
Woodward, H.
Woodward, H. B.
Wortman, J. L.
Wright, J.

Zeiller, R.

COMPARATIVE STATEMENT OF THE NUMBER OF THE SOCIETY AT THE CLOSE OF THE YEARS 1901 AND 1902.

	Dec. 31st, 1901.		Dec. 31st, 1902.
Compounders	285	......	289
Contributing Fellows	925	......	930
Non-contributing Fellows	42	......	39
	1252		1258
Foreign Members	40	......	40
Foreign Correspondents	38	......	39
	1330		1337

Comparative Statement, explanatory of the Alterations in the Number of Fellows, Foreign Members, and Foreign Correspondents at the close of the years 1901 and 1902.

Number of Compounders, Contributing and Non-contributing Fellows, December 31st, 1901		1252
Add Fellows elected during the former year and paid in 1902		18
Add Fellows elected and paid in 1902		30
		1300
Deduct Compounders deceased	6	
Contributing Fellows deceased	11	
Non-contributing Fellows deceased	3	
Contributing Fellows resigned	11	
Contributing Fellows removed	11	
	—	42
		1258
Number of Foreign Members and Foreign Correspondents, December 31st, 1901	78	
Deduct Foreign Correspondents deceased	2	
	76	
Add Foreign Correspondents elected	3	
	—	79
		1337

Deceased Fellows.

Compounders (6).

Andrew, T., Esq.
Gunn, W., Esq.
King, Hon. C.
Morgans, W., Esq.
Selwyn, Dr. A. R. C.
Wiltshire, Rev. Prof. T.

Resident and other Contributing Fellows (11).

Barnard, W. H., Esq.
Brown, J., Esq.
Carrall, J. W., Esq.
Duncombe, Hon. C.
Landon, J., Esq.
Macpherson, J., Esq.
Penning, W. H., Esq.
Rufford, P. J., Esq.
Sparrow, J., Esq.
Stevenson, F., Esq.
Wilson, C. L. N., Esq.

Non-contributing Fellows (3).

Mansel-Pleydell, J. C., Esq.
Morgan, Rev. F. H.
Smithe, Rev. F.

Deceased Foreign Correspondents (2).

Hyatt, Prof. A.
Powell, Major J. W.

Fellows Resigned (11).

Alcock, Major A.
André, G. G., Esq.
Bickford, J. S. V., Esq.
Carmichael, D., Esq.
Crombie, Rev. J. M.
Cunningham, Prof. R. O.
Davey, H., Esq.
Graves, H., Esq.
Holt, H. P., Esq.
Pollen, Rev. G. C. H.
Rickard, T. A., Esq.

Fellows Removed (11).

Biddell, E. S. B., Esq.
Blatchford, T., Esq.
Cragg, A. R., Esq.
Ede, F. J., Esq.
Foster, Rev. H. B.
Lancaster, W. J., Esq.
Lee, J. B., Esq.
Mactear, J. A., Esq.
Turton, A. H., Esq.
Vanstone, Rev. W. J. N.
Whittington, T. D., Esq.

The following Personages were elected Foreign Correspondents during the year 1902 :—

Prof. Thomas Chrowder Chamberlin, of Chicago.
Dr. Thorvaldr Thoroddsen, of Copenhagen.
Prof. Samuel Wendell Williston, of Chicago.

After the Reports had been read, it was resolved :—

That they be received and entered on the Minutes of the Meeting, and that such parts of them as the Council shall think fit be printed and circulated among the Fellows.

It was afterwards resolved :—

That the thanks of the Society be given to Mr. J. E. Marr and Prof. H. G. Seeley, retiring from the office of Vice-President.

That the thanks of the Society be given to Mr. W. H. Hudleston, Rt. Rev. John Mitchinson, Dr. D. H. Scott, Mr. A. Sopwith, and Dr. Henry Woodward, retiring from the Council.

After the Balloting-glasses had been closed, and the Lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected as the Officers and Council for the ensuing year :—

OFFICERS AND COUNCIL.—1903.

PRESIDENT.

Prof. Charles Lapworth, LL.D., F.R.S.

VICE-PRESIDENTS.

Sir Archibald Geikie, D.Sc., D.C.L., LL.D., F.R.S. L. & E.
Prof. H. A. Miers, M.A., F.R.S.
E. T. Newton, Esq., F.R.S.
J. J. H. Teall, Esq., M.A., F.R.S.

SECRETARIES.

R. S. Herries, Esq., M.A.
Prof. W. W. Watts, M.A.

FOREIGN SECRETARY.

Sir John Evans, K.C.B., D.C.L., LL.D., F.R.S., F.L.S.

TREASURER.

W. T. Blanford, LL.D., F.R.S.

COUNCIL.

The Rt. Hon. Lord Avebury, P.C., D.C.L., LL.D., F.R.S., F.L.S.
F. A. Bather, M.A., D.Sc.
W. T. Blanford, LL.D., F.R.S.
Sir John Evans, K.C.B., D.C.L., LL.D., F.R.S.
Prof. E. J. Garwood, M.A.
Sir Archibald Geikie, D.Sc., D.C.L., LL.D., F.R.S. L. & E.
Prof. T. T. Groom, M.A., D.Sc.
Alfred Harker, Esq., M.A., F.R.S.
R. S. Herries, Esq., M.A.
R. Logan Jack, LL.D.
Prof. J. W. Judd, C.B., D.Sc., LL.D., F.R.S.
Percy F. Kendall, Esq.
Prof. Charles Lapworth, LL.D., F.R.S.
Lieut.-General C. A. McMahon, F.R.S.
J. E. Marr, Esq., M.A., F.R.S.
Prof. H. A. Miers, M.A., F.R.S.
H. W. Monckton, Esq., F.L.S.
E. T. Newton, Esq., F.R.S.
G. T. Prior, Esq., M.A.
Prof. H. G. Seeley, F.R.S., F.L.S.
Prof. W. J. Sollas, M.A., D.Sc., LL.D., F.R.S.
J. J. H. Teall, Esq., M.A., F.R.S.
Prof. W. W. Watts, M.A.

LIST OF

THE FOREIGN MEMBERS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1902.

Date of Election.

1874. Prof. Albert Jean Gaudry, *Paris.*
1877. Prof. Eduard Suess, *Vienna.*
1880. Prof. Gustave Dewalque, *Liége.*
1880. Prof. Ferdinand Zirkel, *Leipzig.*
1884. Commendatore Prof. G. Capellini, *Bologna.*
1885. Prof. Jules Gosselet, *Lille.*
1886. Prof. Gustav Tschermak, *Vienna.*
1887. Prof. J. P. Lesley, *Philadelphia, Pa., U.S.A.*
1888. Prof. Eugène Renevier, *Lausanne.*
1888. Baron Ferdinand von Richthofen, *Berlin.*
1889. Prof. Ferdinand Fouqué, *Paris.*
1889. Geheimrath Prof. Karl Alfred von Zittel, *Munich.*
1890. Geheimrath Prof. Heinrich Rosenbusch, *Heidelberg.*
1891. Prof. Charles Barrois, *Lille.*
1893. Prof. Waldemar Christofer Brœgger, *Christiania.*
1893. M. Auguste Michel-Lévy, *Paris.*
1893. Dr. Edmund Mojsisovics von Mojsvár, *Vienna.*
1893. Dr. Alfred Gabriel Nathorst, *Stockholm.*
1894. Prof. George J. Brush, *New Haven, Conn., U.S.A.*
1894. Prof. Edward Salisbury Dana, *New Haven, Conn., U.S.A.*
1894. Prof. Alphonse Renard, *Ghent.*
1895. Prof. Grove Karl Gilbert, *Washington, D.C., U.S.A.*
1895. Dr. Friedrich Schmidt, *St. Petersburg.*
1896. Prof. Albert Heim, *Zürich.*
1897. M. E. Dupont, *Brussels.*
1897. Dr. Anton Fritsch, *Prague.*
1897. Prof. Albert de Lapparent, *Paris.*
1897. Dr. Hans Reusch, *Christiania.*
1898. Geheimrath Prof. Hermann Credner, *Leipzig.*
1898. Mr. Charles Doolittle Walcott, *Washington, D.C., U.S.A.*
1899. Prof. Marcel Bertrand, *Paris.*
1899. Senhor Joaquim Felipe Nery Delgado, *Lisbon.*
1899. Prof. Emmanuel Kayser, *Marburg.*
1899. M. Ernest Van den Broeck, *Brussels.*
1899. Dr. Charles Abiathar White, *Washington, D.C., U.S.A.*
1900. M. Gustave F. Dollfus, *Paris.*
1900. Prof. Paul Groth, *Munich.*
1900. Dr. Sven Leonhard Tœrnquist, *Lund.*
1901. Dr. Alexander Petrovich Karpinsky, *St. Petersburg.*
1901. Prof. Alfred Lacroix, *Paris.*

LIST OF

THE FOREIGN CORRESPONDENTS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1902.

Date of Election.

1866. Prof. Victor Raulin, *Montfaucon d'Argonne.*
1874. Prof. Igino Cocchi, *Florence.*
1879. Dr. Émile Sauvage, *Boulogne-sur-Mer.*
1889. M. R. D. M. Verbeek, *Buitenzorg, Java.*
1890. Herr Felix Karrer, *Vienna.*
1890. Prof. Adolph von Kœnen, *Göttingen.*
1892. Prof. Johann Lehmann, *Kiel.*
1892. Major John W. Powell, *Washington, D.C., U.S.A.* (*Deceased.*)
1893. Prof. Aléxis Pavlow, *Moscow.*
1893. M. Ed. Rigaux, *Boulogne-sur-Mer.*
1894. Prof. Joseph Paxson Iddings, *Chicago, Ill., U.S.A.*
1894. M. Perceval de Loriol-Lefort, *Campagne Frontenex.*
1894. Dr. Francisco P. Moreno, *La Plata.*
1894. Prof. August Rothpletz, *Munich.*
1894. Prof. J. H. L. Vogt, *Christiania.*
1895. Prof. Konstantin de Kroustchoff, *St. Petersburg.*
1895. Prof. Albrecht Penck, *Vienna.*
1896. Prof. S. L. Penfield, *New Haven, Conn., U.S.A.*
1896. Prof. Johannes Walther, *Jena.*
1897. M. Louis Dollo, *Brussels.*
1897. Prof. Anton Koch, *Budapest.*
1897. M. Emmanuel de Margerie, *Paris.*
1897. Prof. Count H. zu Solms-Laubach, *Strasburg.*
1898. Dr. Marcellin Boule, *Paris.*
1898. Dr. W. H. Dall, *Washington, D.C., U.S.A.*
1899. Prof. Charles Emerson Beecher, *New Haven, Conn., U.S.A.*
1899. Dr. Gerhard Holm, *Stockholm.*
1899. Prof. Theodor Liebisch, *Göttingen.*
1899. Prof. Franz Lœwinson-Lessing, *St. Petersburg.*
1899. M. Michel F. Mourlon, *Brussels.*
1899. Prof. Henry Fairfield Osborn, *New York, U.S.A.*
1899. Prof. Gregorio Stefanescu, *Bucharest.*
1899. Prof. René Zeiller, *Paris.*
1900. Prof. Arturo Issel, *Genoa.*
1900. Prof. Ernst Koken, *Tübingen.*
1900. Prof. Federico Sacco, *Turin.*
1901. Prof. Friedrich Johann Becke, *Vienna.*
1902. Prof. Thomas Chrowder Chamberlin, *Chicago, Ill., U.S.A.*
1902. Dr. Thorvaldr Thoroddsen, *Copenhagen.*
1902. Prof. Samuel Wendell Williston, *Chicago, Ill., U.S.A.*

AWARDS OF THE WOLLASTON MEDAL

UNDER THE CONDITIONS OF THE 'DONATION FUND'

ESTABLISHED BY

WILLIAM HYDE WOLLASTON, M.D., F.R.S., F.G.S., ETC.

'To promote researches concerning the mineral structure of the earth, and to enable the Council of the Geological Society to reward those individuals of any country by whom such researches may hereafter be made,'—'such individual not being a Member of the Council.'

1831. Mr. William Smith.
1835. Dr. G. A. Mantell.
1836. M. Louis Agassiz.
1837. { Capt. T. P. Cautley. / Dr. H. Falconer.
1838. Sir Richard Owen.
1839. Prof. C. G. Ehrenberg.
1840. Prof. A. H. Dumont.
1841. M. Adolphe T. Brongniart.
1842. Baron L. von Buch.
1843. { M. Élie de Beaumont. / M. P. A. Dufrénoy.
1844. Rev. W. D. Conybeare.
1845. Prof. John Phillips.
1846. Mr. William Lonsdale.
1847. Dr. Ami Boué.
1848. Very Rev. W. Buckland.
1849. Sir Joseph Prestwich.
1850. Mr. William Hopkins.
1851. Rev. Prof. A. Sedgwick.
1852. Dr. W. H. Fitton.
1853. { M. le Vicomte A. d'Archiac. / M. E. de Verneuil.
1854. Sir Richard Griffith.
1855. Sir Henry De la Beche.
1856. Sir William Logan.
1857. M. Joachim Barrande.
1858. { Herr Hermann von Meyer. / Prof. James Hall.
1859. Mr. Charles Darwin.
1860. Mr. Searles V. Wood.
1861. Prof. Dr. H. G. Bronn.
1862. Mr. R. A. C. Godwin-Austen.
1863. Prof. Gustav Bischof.
1864. Sir Roderick Murchison.
1865. Dr. Thomas Davidson.
1866. Sir Charles Lyell.
1867. Mr. G. Poulett Scrope.
1868. Prof. Carl F. Naumann.
1869. Dr. Henry C. Sorby.
1870. Prof. G. P. Deshayes.
1871. Sir Andrew Ramsay.
1872. Prof. James D. Dana.
1873. Sir P. de M. Grey Egerton.
1874. Prof. Oswald Heer.
1875. Prof. L. G. de Koninck.
1876. Prof. Thomas H. Huxley.
1877. Mr. Robert Mallet.
1878. Dr. Thomas Wright.
1879. Prof. Bernhard Studer.
1880. Prof. Auguste Daubrée.
1881. Prof. P. Martin Duncan.
1882. Dr. Franz Ritter von Hauer.
1883. Dr. William Thomas Blanford.
1884. Prof. Albert Jean Gaudry.
1885. Mr. George Busk.
1886. Prof. A. L. O. Des Cloizeaux.
1887. Mr. John Whitaker Hulke.
1888. Mr. Henry B. Medlicott.
1889. Prof. Thomas George Bonney.
1890. Prof. W. C. Williamson.
1891. Prof. John Wesley Judd.
1892. Baron Ferdinand von Richthofen.
1893. Prof. Nevil Story Maskelyne.
1894. Prof. Karl Alfred von Zittel.
1895. Sir Archibald Geikie.
1896. Prof. Eduard Suess.
1897. Mr. Wilfrid H. Hudleston.
1898. Prof. Ferdinand Zirkel.
1899. Prof. Charles Lapworth.
1900. Prof. Grove Karl Gilbert.
1901. Prof. Charles Barrois.
1902. Dr. Friedrich Schmidt.
1903. Prof. Heinrich Rosenbusch.

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE WOLLASTON 'DONATION FUND.'

1831. Mr. William Smith.
1833. Mr. William Lonsdale.
1834. M. Louis Agassiz.
1835. Dr. G. A. Mantell.
1836. Prof. G. P. Deshayes.
1838. Sir Richard Owen.
1839. Prof. C. G. Ehrenberg.
1840. Mr. J. De Carle Sowerby.
1841. Prof. Edward Forbes.
1842. Prof. John Morris.
1843. Prof. John Morris.
1844. Mr. William Lonsdale.
1845. Mr. Geddes Bain.
1846. Mr. William Lonsdale.
1847. M. Alcide d'Orbigny.
1848. { Cape-of-Good-Hope Fossils. M. Alcide d'Orbigny. }
1849. Mr. William Lonsdale.
1850. Prof. John Morris.
1851. M. Joachim Barrande.
1852. Prof. John Morris.
1853. Prof. L. G. de Koninck.
1854. Dr. S. P. Woodward.
1855. Drs. G. and F. Sandberger.
1856. Prof. G. P. Deshayes.
1857. Dr. S. P. Woodward.
1858. Prof. James Hall.
1859. Mr. Charles Peach.
1860. { Prof. T. Rupert Jones. Mr. W. K. Parker. }
1861. Prof. Auguste Daubrée.
1862. Prof. Oswald Heer.
1863. Prof. Ferdinand Senft.
1864. Prof. G. P. Deshayes.
1865. Mr. J. W. Salter.
1866. Dr. Henry Woodward.
1867. Mr. W. H. Baily.
1868. M. J. Bosquet.
1869. Mr. William Carruthers.
1870. M. Marie Rouault.
1871. Mr. Robert Etheridge.
1872. Dr. James Croll.
1873. Prof. John Wesley Judd.
1874. Dr. Henri Nyst.
1875. Prof. L. C. Miall.
1876. Prof. Giuseppe Seguenza.
1877. Mr. R. Etheridge, Jun.
1878. Prof. William Johnson Sollas.
1879. Mr. Samuel Allport.
1880. Mr. Thomas Davies.
1881. Dr. Ramsay Heatley Traquair.
1882. Dr. George Jennings Hinde.
1883. Prof. John Milne.
1884. Mr. Edwin Tulley Newton.
1885. Dr. Charles Callaway.
1886. Mr. J. Starkie Gardner.
1887. Mr. Benjamin Neeve Peach.
1888. Dr. John Horne.
1889. Dr. Arthur Smith Woodward.
1890. Mr. William A. E. Ussher.
1891. Mr. Richard Lydekker.
1892. Mr. Orville Adelbert Derby.
1893. Mr. John George Goodchild.
1894. Mr. Aubrey Strahan.
1895. Prof. W. W. Watts.
1896. Mr. Alfred Harker.
1897. Dr. Francis Arthur Bather.
1898. Prof. Edmund J. Garwood.
1899. Prof. John B. Harrison.
1900. Mr. George Thurland Prior.
1901. Mr. Arthur Walton Rowe.
1902. Mr. Leonard James Spencer.
1903. Mr. L. L. Belinfante.

AWARDS OF THE MURCHISON MEDAL

UNDER THE CONDITIONS OF THE

'MURCHISON GEOLOGICAL FUND,'

ESTABLISHED UNDER THE WILL OF THE LATE

SIR RODERICK IMPEY MURCHISON, Bart., F.R.S., F.G.S.

'To be applied in every consecutive year in such manner as the Council of the Society may deem most useful in advancing Geological Science, whether by granting sums of money to travellers in pursuit of knowledge, to authors of memoirs, or to persons actually employed in any enquiries bearing upon the science of Geology, or in rewarding any such travellers, authors, or other persons, and the Medal to be given to some person to whom such Council shall grant any sum of money or recompense in respect of Geological Science.'

1873. Mr. William Davies.
1874. Dr. J. J. Bigsby.
1875. Mr. W. J. Henwood.
1876. Mr. Alfred R. C. Selwyn.
1877. Rev. W. B. Clarke.
1878. Prof. Hanns Bruno Geinitz.
1879. Sir Frederick M'Coy.
1880. Mr. Robert Etheridge.
1881. Sir Archibald Geikie.
1882. Prof. Jules Gosselet.
1883. Prof. H. R. Gœppert.
1884. Dr. Henry Woodward.
1885. Dr. Ferdinand von Rœmer.
1886. Mr. William Whitaker.
1887. Rev. Peter B. Brodie.
1888. Prof. J. S. Newberry.
1889. Prof. James Geikie.
1890. Prof. Edward Hull.
1891. Prof. W. C. Brögger.
1892. Prof. A. H. Green.
1893. Rev. Osmond Fisher.
1894. Mr. William T. Aveline.
1895. Prof. Gustaf Lindstrœm.
1896. Mr. T. Mellard Reade.
1897. Mr. Horace B. Woodward.
1898. Mr. Thomas F. Jamieson.
1899. { Mr. Benjamin N. Peach.
Dr. John Horne.
1900. Baron A. E. Nordenskiœld.
1901. Mr. A. J. Jukes-Browne.
1902. Mr. Frederic W. Harmer.
1903. Dr. Charles Callaway.

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE 'MURCHISON GEOLOGICAL FUND.'

1873. Prof. Oswald Heer.
1874. Mr. Alfred Bell.
1874. Prof. Ralph Tate.
1875. Prof. H. Govier Seeley.
1876. Dr. James Croll.
1877. Rev. John Frederick Blake.
1878. Prof. Charles Lapworth.
1879. Mr. James Walker Kirkby.
1880. Mr. Robert Etheridge.
1881. Mr. Frank Rutley.
1882. Prof. Thomas Rupert Jones.
1883. Dr. John Young.
1884. Mr. Martin Simpson.
1885. Mr. Horace B. Woodward.
1886. Mr. Clement Reid.
1887. Mr. Robert Kidston.
1888. Mr. Edward Wilson.
1889. Prof. Grenville A. J. Cole.
1890. Mr. Edward B. Wethered.
1891. Rev. Richard Baron.
1892. Mr. Beeby Thompson.
1893. Mr. Griffith J. Williams.
1894. Mr. George Barrow.
1895. Mr. Albert Charles Seward.
1896. Mr. Philip Lake.
1897. Mr. Sydney S. Buckman.
1898. Miss Jane Donald.
1899. Mr. James Bennie.
1900. Mr. A. Vaughan Jennings.
1901. Mr. Thomas S. Hall.
1902. Mr. Thomas H. Holland.
1903. Mrs. Elizabeth Gray.

AWARDS OF THE LYELL MEDAL

UNDER THE CONDITIONS OF THE

'LYELL GEOLOGICAL FUND,'

ESTABLISHED UNDER THE WILL AND CODICIL OF THE LATE

SIR CHARLES LYELL, Bart., F.R.S., F.G.S.

The Medal 'to be given annually' (or from time to time) 'as a mark of honorary distinction and as an expression on the part of the governing body of the Society that the Medallist (who may be of any country or either sex) has deserved well of the Science,'—'not less than one third of the annual interest [of the fund] to accompany the Medal, the remaining interest to be given in one or more portions at the discretion of the Council for the encouragement of Geology or of any of the allied sciences by which they shall consider Geology to have been most materially advanced, either for travelling expenses or for a memoir or paper published, or in progress, and without reference to the sex or nationality of the author, or the language in which any such memoir or paper may be written.'

1876. Prof. John Morris.
1877. Sir James Hector.
1878. Mr. George Busk.
1879. Prof. Edmond Hébert.
1880. Sir John Evans.
1881. Sir J. William Dawson.
1882. Dr. J. Lycett.
1883. Dr. W. B. Carpenter.
1884. Dr. Joseph Leidy.
1885. Prof. H. Govier Seeley.
1886. Mr. William Pengelly.
1887. Mr. Samuel Allport.
1888. Prof. Henry A. Nicholson.
1889. Prof. W. Boyd Dawkins.
1890. Prof. Thomas Rupert Jones.
1891. Prof. T. McKenny Hughes.
1892. Mr. George H. Morton.
1893. Mr. E. Tulley Newton.
1894. Prof. John Milne.
1895. Rev. John Frederick Blake.
1896. Dr. A. Smith Woodward.
1897. Dr. George Jennings Hinde.
1898. Prof. Wilhelm Waagen.
1899. Lt.-Gen. C. A. McMahon.
1900. Mr. John Edward Marr.
1901. Dr. Ramsay H. Traquair.
1902. { Prof. Anton Fritsch.
Mr. Richard Lydekker.
1903. Mr. Frederick William Rudler.

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE 'LYELL GEOLOGICAL FUND.'

1876. Prof. John Morris.
1877. Mr. William Pengelly.
1878. Prof. Wilhelm Waagen.
1879. Prof. Henry A. Nicholson.
1879. Dr. Henry Woodward.
1880. Prof. F. A. von Quenstedt.
1881. Prof. Anton Fritsch.
1881. Mr. G. R. Vine.
1882. Rev. Norman Glass.
1882. Prof. Charles Lapworth.
1883. Mr. P. H. Carpenter.
1883. M. Ed. Rigaux.
1884. Prof. Charles Lapworth.
1885. Mr. A. J. Jukes-Browne.
1886. Mr. D. Mackintosh.
1887. Rev. Osmond Fisher.
1888. Dr. Arthur H. Foord.
1888. Mr. Thomas Roberts.
1889. M. Louis Dollo.
1890. Mr. C. Davies Sherborn.
1891. Dr. C. I. Forsyth-Major.
1891. Mr. George W. Lamplugh.
1892. Prof. J. Walter Gregory.
1892. Mr. Edwin A. Walford.
1893. Miss Catherine A. Raisin.
1893. Mr. Alfred N. Leeds.
1894. Mr. William Hill.
1895. Mr. Percy Fry Kendall.
1895. Mr. Benjamin Harrison.
1896. Dr. William F. Hume.
1896. Dr. Charles W. Andrews.
1897. Mr. W. J. Lewis Abbott.
1897. Mr. Joseph Lomas.
1898. Mr. William H. Shrubsôle.
1898. Mr. Henry Woods.
1899. Mr. Frederick Chapman.
1899. Mr. John Ward.
1900. Miss Gertrude L. Elles.
1901. Dr. John William Evans.
1901. Mr. Alexander McHenry.
1902. Dr. Wheelton Hind.
1903. Mr. Sydney S. Buckman.
1903. Mr. George Edward Dibley.

AWARD OF THE PRESTWICH MEDAL,

ESTABLISHED UNDER THE WILL OF THE LATE

SIR JOSEPH PRESTW F.R.S., F.G.S.

'To apply the accumulated annual proceeds . . . at the end of every three (or every six) years in providing a Gold Medal . . . to be awarded . . . to the person or persons, either male or female, and either resident in England or abroad, who shall have done well for the advancement of the science of Geology.'

1903. John Lubbock, Baron Avebury.

AWARDS OF THE BIGSBY MEDAL,

FOUNDED BY THE LATE

DR. J. J. BIGSBY, F.R.S., F.G.S.

To be awarded biennially 'as an acknowledgement of eminent services in any department of Geology, irrespective of the receiver's country; but he must not be older than 45 years at his last birthday, thus probably not too old for further work, and not too young to have done much.'

1877. Prof. Othniel C. Marsh.
1879. Prof. Edward D. Cope.
1881. Prof. Charles Barrois.
1883. Dr. Henry Hicks.
1885. Prof. Alphonse Renard.
1887. Prof. Charles Lapworth.
1889. Mr. J. J. Harris Teall.
1891. Dr. George M. Dawson.
1893. Prof. William J. Sollas.
1895. Mr. Charles D. Walcott.
1897. Mr. Clement Reid.
1899. Prof. T. W. E. David.
1901. Mr. George W. Lamplugh.
1903. Dr. Henry M. Ami.

AWARDS OF THE PROCEEDS OF THE BARLOW-JAMESON FUND,

ESTABLISHED UNDER THE WILL OF THE LATE

DR. H. C. BARLOW, F.G.S.

'The perpetual interest to be applied every two or three years, as may be approved by the Council, to or for the advancement of Geological Science.'

1879. Purchase of Microscope.
1881. Purchase of Microscope-Lamps.
1882. Baron C. von Ettingshausen.
1884. Dr. James Croll.
1884. Prof. Leo Lesquereux.
1886. Dr. H. J. Johnston-Lavis.
1888. Museum.
1890. Mr. W. Jerome Harrison.
1892. Prof. Charles Mayer-Eymar.
1893. Purchase of Scientific Instruments for Capt. F. E. Younghusband.
1894. Dr. Charles Davison.
1896. Mr. Joseph Wright.
1896. Mr. John Storrie.
1898. Mr. Edward Greenly.
1900. Mr. George C. Crick.
1900. Prof. Theodore T. Groom.
1902. Mr. William M. Hutchings.

Estimates for

INCOME EXPECTED.

	£	s.	d.	£	s.	d.
Compositions				238	0	0
Due for Arrears of Admission Fees	107	2	0			
Admission Fees, 1903	200	0	0			
				307	2	0
Arrears of Annual Contributions	170	0	0			
Annual Contributions, 1903, from Resident Fellows and Non-Residents	1750	0	0			
Annual Contributions in advance	45	0	0			
				1965	0	0
Sale of Quarterly Journal, including Longmans' Account				150	0	0
Sale of Transactions, Library Catalogue, General Index, Hutton's 'Theory of the Earth' vol. iii, Hochstetter's 'New Zealand,' Museum Catalogue, and List of Fellows				5	10	0
Dividends on £2500 India 3 per cent. Stock ..	75	0	0			
Dividends on £300 London, Brighton, & South Coast Railway 5 per cent. Consolidated Preference Stock	15	0	0			
Dividends on £2250 London & North-Western Railway 4 per cent. Preference Stock	90	0	0			
Dividends on £2800 London & South-Western Railway 4 per cent. Preference Stock	112	0	0			
Dividends on £2072 Midland Railway $2\frac{1}{2}$ per cent. Perpetual Preference Stock	51	16	0			
Dividends on £267 6*s.* 7*d.* Natal 3 per cent. Stock.	8	0	0			
				351	16	0
				£3017	8	0

the Year 1903.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
House Expenditure:						
Taxes		15	0			
Fire Insurance	15	0	0			
Electric Lighting	40	0	0			
Gas	12	0	0			
Fuel	45	0	0			
Furniture and Repairs	30	0	0			
House-Repairs and Maintenance	30	0	0			
Annual Cleaning	15	0	0			
Washing and Sundry Expenses	35	0	0			
Tea at Meetings	20	0	0			
				242	15	0
Salaries and Wages, etc.:						
Assistant Secretary	350	0	0			
,, half Premium Life Assurance	10	15	0			
Assistant Librarian	150	0	0			
Assistant Clerk	140	0	0			
Junior Assistant	52	0	0			
House Porter and Housemaid	94	10	0			
Under Housemaid	48	18	0			
Charwoman and Occasional Assistance	10	0	0			
Accountant's Fee	10	10	0			
				866	13	0
Office Expenditure:						
Stationery	35	0	0			
Miscellaneous Printing	50	0	0			
Postages and Sundry Expenses	85	0	0			
				170	0	0
Library (Books and Binding)				200	0	0
Library Catalogue				90	0	0
International Catalogue of Scientific Literature				60	0	0
Museum				5	0	0
Museum Catalogue				100	0	0
Publications:						
Quarterly Journal, including Commission on Sale	900	0	0			
Record of Geological Literature	148	0	0			
List of Fellows	35	0	0			
Postage on Journal, Addressing, etc.	90	0	0			
Abstracts, including Postage	110	0	0			
				1283	0	0
				£3017	8	0

W. T. BLANFORD, *Treasurer.*

January 28th, 1903.

Income and Expenditure during the

RECEIPTS.

	£	s.	d.	£	s.	d.
To Balance in the hands of the Bankers at January 1st, 1902:						
On Current Account	132	4	2			
On Deposit Account	250	0	0			
,, Balance in the hands of the Clerk at January 1st, 1902	21	8	1			
				403	12	3
,, Compositions				339	10	0
,, Admission Fees:						
Arrears	113	8	0			
Current	189	0	0			
				302	8	0
,, Arrears of Annual Contributions	96	12	0			
,, Annual Contributions of 1902:						
Resident Fellows	1726	14	6			
Non-Resident Fellows	7	17	6			
,, Annual Contributions in advance	48	6	0			
				1879	10	0
,, Publications:						
Sale of Quarterly Journal:						
,, Vols. i to lvii *	88	9	10			
,, Vol. lviii *	68	2	11			
				156	12	9
,, Transactions		10	0			
,, Record of Geological Literature	1	7	6			
,, Hutton's 'Theory of the Earth' vol. iii		14	0			
,, Museum Catalogue	8	4	0			
,, List of Fellows		8	0			
				11	3	6
,, Repayment of Income Tax				16	1	5
,, Dividends (less Income Tax):—						
£2500 India 3 per cent. Stock....	70	9	3			
£300 London, Brighton, & South Coast Railway 5 per cent. Consolidated Preference Stock	14	2	2			
£2250 London & North-Western Railway 4 per cent. Preference Stock	84	13	1			
£2800 London & South-Western Railway 4 per cent. Preference Stock	105	7	0			
£2072 Midland Railway $2\frac{1}{2}$ per cent. Perpetual Preference Stock	48	14	5			
£267 6*s.* 7*d.* Natal 3 per cent. Stock	3	15	2			
				327	1	1
,, Interest on Deposit				3	17	3
				£3439	16	3

* Due from Messrs. Longmans, in addition to the above, on Journal, Vol. lviii, etc. £67 0 7

Year ended December 31st, 1902.

PAYMENTS.

	£ s. d.	£ s. d.
By House Expenditure:		
Taxes	15 0	
Fire Insurance	15 0 0	
Electric Lighting	33 15 2	
Gas	11 15 10	
Fuel	12 10 2	
Furniture and Repairs	118 3 7	
House-Repairs and Maintenance	36 6 6	
Annual Cleaning	13 6 6	
Washing and Sundry Expenses	30 10 7	
Tea at Meetings	18 18 6	
Coronation Decorations	15 0 0	
		306 1 10
,, Salaries and Wages:		
Assistant Secretary	350 0 0	
,, ,, half Premium Life Assurance	10 15 0	
Assistant Librarian	150 0 0	
Assistant Clerk	120 0 0	
Junior Assistant	38 12 0	
House Porter and Upper Housemaid	93 0 3	
Under Housemaid	48 5 6	
Charwoman and Occasional Assistance	8 17 0	
Accountant's Fees	11 15 0	
Solicitors' Fees	11 6 0	
		842 10 9
,, Office Expenditure:		
Stationery	31 18 8	
Miscellaneous Printing	59 9 9	
Postages and Sundry Expenses	85 18 0	
		177 6 5
,, Library (Books and Binding)		266 1 5
,, Library Catalogue		89 11 8
,, International Catalogue of Scientific Literature		60 6 4
,, Publications:		
Quarterly Journal, Vols. i to lvii, Commission on Sale thereof	7 14 4	
Quarterly Journal, Vol. lviii, Commission on Sale thereof	5 11 0	
Paper, Printing, and Illustrations	963 13 1	
Record of Geological Literature	152 10 3	
List of Fellows	36 0 0	
Postage on Journal, Addressing, etc.	92 14 3	
Abstracts, including Postage	112 16 8	
		1370 19 7
,, Electric-Light Installation and Repairs		15 10 7
,, Purchase of £267 6*s.* 7*d.* 3 per cent. Natal Stock @ $93\frac{1}{4}$		250 0 0
,, Balance in the hands of the Bankers at December 31st, 1902:		
On Current Account	56 15 11	
,, Balance in the hands of the Clerk	4 11 9	
		61 7 8
		£3439 16 3

We have compared this Statement with the Books and Accounts presented to us, and find them to agree.

F. W. RUDLER,
EDMUND J. GARWOOD, } *Auditors.*

W. T. BLANFORD, *Treasurer.*

January 28th, 1903.

Statement of Trust Funds: December 31st, 1902

'Wollaston Donation Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1902	30	8	10	By Award to Mr. L. J. Spencer, and Medal	30	8	10
„ Dividends (less Income Tax) on the Fund invested in £1073 Hampshire County 3 per cent. Stock	30	4	10	„ Balance at the Bankers', December 31st, 1902	31	17	1
„ Income Tax recovered	1	12	3				
	£62	5	11		£62	5	11

'Murchison Geological Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1902	18	18	6	By Award to Mr. F. W. Harmer	10	10	0
„ Dividends (less Income Tax) on the Fund invested in £1334 London & North-Western Railway 3 per cent. Debenture Stock	37	12	10	„ „ Mr. T. H. Holland	26	8	4
„ Income Tax recovered	1	16	8	„ Cost of Medal		17	0
				„ Balance at the Bankers', December 31st, 1902	20	12	8
	£58	8	0		£58	8	0

'Lyell Geological Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1902	49	16	8	By Award to Mr. R. Lydekker	25	0	0
„ Dividends (less Income Tax) on the Fund invested in £2010 1*s.* 0*d.* Metropolitan 3½ per cent. Stock	66	2	2	„ „ Dr. A. Fritsch	25	0	0
„ Income Tax recovered	3	10	4	„ „ Dr. Wheelton Hind	14	5	11
				„ Cost of Medals	2	2	0
				„ Balance at the Bankers', December 31st, 1902	53	1	3
	£119	9	2		£119	9	2

'Barlow-Jameson Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1902	22	1	7	By Award to Mr. W. M. Hutchings	21	0	0
„ Dividends (less Income Tax) on the Fund invested in £468 Great Northern Railway 3 per cent. Debenture Stock	13	4	2	„ „ Dr. Wheelton Hind	6	14	1
„ Income Tax recovered		12	10	„ Balance at the Bankers', December 31st, 1902	8	4	6
	£35	18	7		£35	18	7

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1902	2	19	4	By Balance at the Bankers', December 31st, 1902	9	4	1
„ Dividends (less Income Tax) on the Fund invested in £210 Cardiff 3 per cent. Stock	5	18	5				
„ Income Tax recovered		6	4				
	£9	4	1		£9	4	1

'Geological Relief Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1902	11	18	5	By Grants	6	6	0
„ Dividends (less Income Tax) on the Fund invested in £139 3*s.* 7*d.* India 3 per cent. Stock	3	18	5	„ Balance at the Bankers', December 31st, 1902	9	15	0
„ Income Tax recovered		4	2				
	£16	1	0		£16	1	0

'Prestwich Trust Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1902	29	9	9	By Cost of Medal Dies	30	0	0
„ Dividends (less Income Tax) on the Fund invested in £591 1*s.* 4*d.* India 3 per cent. Stock	16	13	4	„ Balance at the Bankers', December 31st, 1902	17	0	9
„ Income Tax recovered		17	8				
	£47	0	9		£47	0	9

'Daniel Pidgeon Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Cash received from Mrs. Pidgeon's Solicitors on January 27th, 1902	1000	0	0	By Purchase of £1019 1*s.* 2*d.* Bristol Corporation 3 per cent. Stock @ 98	1000	0	0
„ Dividend on £1019 1*s.* 2*d.* Bristol Corporation 3 per cent. Stock	14	6	7	„ Balance at the Bankers', December 31st, 1902	14	6	7
	£1014	6	7		£1014	6	7

We have compared this Statement with the Books and Accounts presented to us, and find them to agree.

W. T. BLANFORD, *Treasurer*.

January 28th, 1903.

F. W. RUDLER,
EDMUND J. GARWOOD, } *Auditors*.

Statement of the Society's Property: December 31st, 1902.

Property.	£	s.	d.		£	s.	d.
Due from Longmans & Co., on account of Quarterly Journal, Vol. LVIII, etc.	67	0	7	Balance in favour of the Society	12,167	19	0
Balance in the Bankers' hands, December 31st, 1902:							
On Current Account	56	15	11				
Balance in the Clerk's hands, December 31st, 1902	4	11	9				
Funded Property:—							
£2500 India 3 per cent. Stock	2623	6	0				
£2250 London & North-Western Railway 4 per cent. Preference Stock	2898	10	6				
£2800 London & South-Western Railway 4 per cent. Preference Stock	3607	7	6				
£300 London, Brighton, & South Coast Railway 5 per cent. Consolidated Preference Stock	502	15	3				
£2072 Midland Railway $2\frac{1}{2}$ per cent. Perpetual Preference Stock	1850	19	6				
£267 6*s.* 7*d.* Natal 3 per cent. Stock	250	0	0				
Arrears of Admission Fees	107	2	0				
Arrears of Annual Contributions	199	10	0				
[*N.B.—The above does not include the value of the Collections, Library, Furniture, and Stock of unsold Publications.*]	£12,167	19	0		£12,167	19	0

W. T. BLANFORD, *Treasurer.*

January 28th, 1903.

Note.—The investments in Stocks are valued at their cost price.

Award of the Wollaston Medal.

In handing the Wollaston Medal, awarded to Geheimrath Prof. Dr. Heinrich Rosenbusch, For.Memb.G.S., of Heidelberg, to Prof. W. J. Sollas, M.A., D.Sc., F.R.S., for transmission to the recipient, the President addressed him as follows:—

Prof. Sollas,—

No man has exercised a greater influence on the progress of petrological science than Prof. Rosenbusch. Though a master of detail, he has always insisted on the important bearing of microscopical studies on many of the great theoretical problems of modern geology.

In his celebrated researches on the Steigen Schiefer he combined stratigraphical, mineralogical, and chemical data in such a manner that his memoir must for all time remain a classic in geological literature. His subsequent work is all of the same philosophical character, and every question that he has handled has been fundamentally modified and notably advanced as the result of his investigations. The fertility which he has shown, in the production of new and often profound theories, has only been equalled by the courage with which he has discarded the old, so soon as they have proved unsatisfactory or incomplete.

The successive editions of his great work on the microscopic characters of minerals and rocks have been landmarks in the progress of the science. The range of knowledge therein revealed is enormous, yet we never feel that his writings are overburdened with detail, because of the power of philosophical generalization with which he marshals his facts, and reduces the whole to a consistent and well co-ordinated unity.

As a teacher Prof. Rosenbusch has especially excelled, and the devotion and enthusiasm both of himself and his pupils have greatly helped to awaken the interest of geologists in petrological investigations, and to give to these investigations the prominent position that they now occupy.

The Council of the Geological Society award their Wollaston Medal to Prof. Rosenbusch, in grateful appreciation of these preeminent services to geological science.

Prof. SOLLAS, in reply, read the following letter which had been forwarded by the recipient :—

'Mr. PRESIDENT,—

'Although the Geological Society, for many years past, has accustomed me to a most benevolent judgment of my scientific work, I feel greatly surprised by the award of the Wollaston Medal, the highest honour which the Council of this illustrious Society can bestow. I beg to offer my cordial thanks for this distinction, which I thought far beyond the limits of my aspirations.

'I may proudly confess to have passed a life of earnest and unceasing endeavour in the attempt to understand and to decipher those grand and mysterious documents, wherein the geological history of our mother Earth has been written down by Nature itself; but I am fully aware of the insignificance of the results obtained. Every word, which it is our good fortune to decipher, involves a new riddle, and so I daily repeat the first scientific experience of my infancy—that the art of spelling is a most difficult one.

'There are many members in this illustrious corporation to whom I owe a vast debt of scientific information and of personal encouragement. The high honour received at their hands on this day will be a stimulus to me for ever-renewed attempts to proceed on my onward way, *γηράσκω δ'αἰεὶ πολλὰ διδασκόμενος*. It will be, indeed, a great satisfaction to me, if the rest of my life's work prove not unworthy of the approbation of this ancient and renowned Society.'

AWARD OF THE MURCHISON MEDAL.

The PRESIDENT then presented the Murchison Medal to Dr. CHARLES CALLAWAY, M.A., addressing him in the following words :—

Dr. CALLAWAY,—

Your work among the ancient rocks of Shropshire—Murchison's classical county—commenced as early as 1874, when you brought before this Society evidences of the occurrence of Tremadoc fossils in the so-called 'Bala' rocks of that area; but your conclusions were then in advance of the times. In your second paper, published in 1878, on a 'New Area of Cambrian Rocks in Shropshire,' however, you not only demonstrated by means of the abundance of fossils the accuracy of those conclusions, but you made that paper the starting-point of those researches which, as afterwards carried out by yourself and others, have effected almost a revolution in our previous knowledge of the older half of Shropshire geology.

You first suggested in that paper the Archæan age of the Wrekin volcanic series, and in several subsequent papers you not only showed the extension of these volcanic and Cambrian rocks into the

Caradoc area and elsewhere, but introduced into the geological literature of our older rock-groups the names Uriconian, Longmyndian, and Malvernian.

Your researches also in the Malvern Hills, in Anglesey, and in the complicated Assynt and other regions of the North-Western Highlands were all of them most fruitful in discovery, and stimulated the work of others in no ordinary degree. And of your later researches into the obscure phenomena of the crystalline and metamorphic rocks, the same may be said. As one of those who have followed your track, to their pleasure and benefit; and as one who has for more than thirty years been honoured by your friendship, it is a great pleasure to me to be permitted to hand you this Medal on behalf of the Council of the Geological Society.

Dr. Callaway replied as follows:—

Mr. President,—

I am deeply sensible of the honour conferred upon me by the award of this Medal. It is to me a special gratification that it bears the name of Murchison, for the greater part of my work has been on ground rendered classic by his genius. We honour him as one of the chief of those who laid the foundations of our knowledge of the oldest rocks, and I am proud to have been able to add a few stones to the superstructure. That I receive this distinction at your hands is a peculiar pleasure. You also have laboured long in the field of Archæan and Proterozoic geology. Your kind and generous appreciation has, therefore, a personal, as well as an official, value.

Award of the Lyell Medal.

In presenting the Lyell Medal to Mr. Frederick William Rudler, late Curator of the Museum of Practical Geology, Jermyn Street, the President addressed him as follows:—

Mr. Rudler,—

Our science demands for its progress not only men who discover new facts, but also men who will explain and illustrate its facts and theories to those who are anxious to understand and to make

use of them. There are few among those who have been both learners and workers in the science during the last thirty years, who do not retain grateful memories of the instruction and assistance which at one time or another you have personally afforded them.

Further, our science needs for its appreciation by the economic world and the public those who, being familiar with the facts already gathered together, will present them in a clear and convincing form, and expound their practical applications. In this respect also you have done our science lasting service. Indeed, your long official career at the Museum of Practical Geology has been a record of unselfish devotion to the advancement of the practical and educational sides of geology.

In countless ways—in reviews, in the later editions of Ure's famous 'Dictionary of Arts, Manufactures, & Mines'; in your masterly essays on 'Experimental Geology,' and on 'Fifty Years' Progress in British Geology,' delivered as Presidential Addresses before the Geologists' Association—not to mention anthropological and other addresses—you have given evidence of your wide knowledge of the literature and substance of geology and the allied sciences, of your sound judgment, and of your exceptional capacity for transmitting to others the accurate knowledge which you possess.

It affords, therefore, to the Council of the Geological Society the greatest satisfaction to award to you the Lyell Medal which, according to the words of its founder, is to be given to one who 'has deserved well of the science.'

Mr. Rudler replied in the following words :—

Mr. President,—

To have the privilege of standing here as the recipient of a Medal is a far higher honour than I had ever dared to expect. While acknowledging most gratefully, though I feel most inadequately, the generous action of the Council in making this award, I am also anxious to express my deep sense of indebtedness to you, Sir, for the very indulgent words with which you have been so good as to enrich this presentation. If anything like personal detachment from such an award were permissible, I should like to be allowed to regard this as a token of sympathy between this Society and the institution with which I was so long connected, and where the ruling desire of every officer is—if I may use the words of the illustrious founder of this bequest, which you have just quoted—to

deserve well of geological science. It is, Sir, a matter of extreme gratification to me that I should find myself unexpectedly honoured by the possession of a Medal founded by our great master, whom it was my privilege to know personally, and whose memory I so profoundly revere.

Award of the Bigsby Medal.

The President then presented the Bigsby Medal to Dr. Henry M. Ami, M.A., of the Canadian Geological Survey, addressing him as follows :—

Dr. Ami,—

Those members of the Geological Society who interest themselves in the Palæozoic formations of Britain and America, are well aware of the extent and importance of your work among the Palæozoic rocks and fossils of Canada. As Assistant-Palæontologist to the Canadian Survey, you have not only been for many years responsible for much of the classification and tabulation of the Lower Palæozoic fossils in the Museum of that Survey, but you have visited the places where they were collected in the field, and identified on the spot their local horizons. This twofold knowledge has enabled you in several of your papers, such as those bearing on the 'Geology of Quebec & its Neighbourhood,' the 'Utica Terrane,' and the 'Organic Remains & Geological Formations of the Eastern Townships,' to throw much light on disputed questions of succession and stratigraphy.

Nor has your work been restricted to the older Palæozoic rocks. Your papers on the 'Knoydart Formation of Nova Scotia,' the 'Carboniferous Formations of Canada,' etc., have done much to clear up the difficulties of the correlation of these formations with those of other countries. Neither must we forget the many papers in which you, with fulness of knowledge and great depth of sympathy, have laid before geologists and the public the lives and labours of those great pioneers who have accumulated the vast store of knowledge which we now possess of the rocks and fossils of the Dominion.

As an old friend and correspondent of yours, I am very pleased that it has fallen to my lot to hand you this Medal; and I can assure you, on behalf of the Council of the Geological Society of

London, that it is a special gratification to them to award it to one whose work has been done in the country of the founder of the Medal himself, and among the rocks and fossils studied by him.

Dr. Ami replied in the following words:—

Mr. President,—

I am deeply sensible of the great honour which the Council of this Society have conferred upon me. Especially am I gratified in receiving this Award at the hands of one who has been so generous a counsellor and critic in matters geological for the past eighteen years. Words fail me to express in adequate terms the gratitude which fills me at present. Suffice it to say, that through the liberality of the Canadian Government and the courtesy of the Hon. the Minister of the Interior (Mr. Clifford Sifton), Head of the Geological Survey Department at Ottawa, I have acceded to his wishes, and come over in person to receive at your hands the award so generously made.

It is always a source of inspiration to come to London, the centre of thought, the fountain-head of research and radiator of power; and, believe me, that, combined with the pleasure and privilege of attending one of the Anniversary Meetings of this Society, of which I have been a humble Fellow for some eighteen years, there lurked in my mind the thought of gain in valuable information during my stay, which I know will enable me all the better and more intelligently to carry out the special work on the Silurian faunas and succession of Eastern Canada which has been entrusted to me.

That my name should become associated with that of the late Dr. Bigsby, founder of the Medal, is a matter of which I have great reason to be proud. Bigsby was a pioneer in British North American geology. It has been my lot and good fortune recently to collect all the data relating to the geological history of the Grand Manitoulin and adjacent islands of Palæozoic age in the Lake-Huron district of Canada, and it may not be uninteresting to state here, that when the unexpected news of this Award reached me in Ottawa, I had then completed, and on my desk, a synopsis of Dr. Bigsby's geological explorations in that region during the early years of the last century.

In conclusion, permit me to add, that I am deeply moved at this moment by the thought of what the acceptance of the Bigsby Medal on my part involves. There is undoubtedly associated with it a solemn pledge and obligation to prosecute geological research-work still further. If I am spared, Sir, it will be my highest endeavour as well as pleasure and privilege, to follow in the footsteps of those eminent geologists in the distinguished list of recipients of the Medal founded through the generosity of the late Dr. Bigsby, and prove not unworthy of the marked distinction that the Council have conferred upon me this day.

Award of the first Prestwich Medal.

The President, in handing the Prestwich Medal, awarded to the Rt. Hon. John, Baron Avebury, P.C., F.R.S., to Prof. T. G. Bonney, D.Sc., F.R.S., for transmission to the recipient, addressed him in the following words:—

Prof. Bonney,—

Sir John Lubbock, now the Right Honourable Lord Avebury, P.C., became a Fellow of this Society in 1855. He was one of those who took a warm interest in the question of the antiquity of man, in those early days when it was so much in dispute. He did much to support the new views, not only by a paper in the Natural History Review, but also by his work on 'Prehistoric Times,' in which that paper was subsequently incorporated. In those days he was closely associated with Sir Joseph Prestwich (who at that time had not yet been called to the professorial chair at Oxford), and, along with Sir John Evans, frequently accompanied him and other Fellows of the Society on geological excursions in France and elsewhere, investigating not only the evidences of the antiquity of man, but other problems of special interest in geology.

Since then, notwithstanding his numerous public avocations, his important business occupations, and his researches in natural history, both entomological and botanical, he has always retained a lasting attachment to geology. He has evinced this, not only by keeping abreast with its progress, and accompanying its workers in the field, but also in the publication of works on geology, marked by his own literary charm. His recent works

on the scenery of Switzerland and of England have done much to create a deep appreciation and sympathy for the science among the thinking and educated public.

Whether, therefore, from old associations, or from the special nature of his geological researches, or from the fascination of his geological works, the Council of the Geological Society feel that he is a most fitting recipient of the first gold medal struck in accordance with the testamentary dispositions of our venerated Fellow, Sir Joseph Prestwich.

Prof. BONNEY, in reply, read the following letter which had been forwarded to him by the recipient:—

'MR. PRESIDENT,—

'I should have felt it a great compliment in any case that the Geological Society should have bestowed upon me one of their medals, but I am specially gratified to have received the first of the Medals instituted in honour of my old friend, Sir Joseph Prestwich. It is now more than forty years since I first visited the valley of the Somme under his guidance and that of M. Boucher de Perthes. Since then I have had the advantage of making many most instructive excursions with him. On those occasions we were out early and late. Meals constantly gave way to gravel-pits. On one occasion I spent a week with him in Paris,—at least if we can be said to have been in Paris, when I think that we were never there between 7 o'clock in the morning and 8 in the evening, and I look back on those expeditions with the greatest interest. I shall value the Medal extremely, both as a mark of the approval of the Council, and also in memory of one whom I esteemed so highly, and to whom I owed so much. It is a matter of great regret to me that absence from England has precluded me from attending to receive it personally.'

AWARD OF THE WOLLASTON DONATION FUND.

The PRESIDENT then presented the Balance of the Proceeds of the Wollaston Donation Fund to Mr. L. L. BELINFANTE, M.Sc., Assistant Secretary of the Geological Society, addressing him as follows:—

MR. BELINFANTE,—

At a meeting of Fellows of the Geological Society it is quite unnecessary for me to say anything as to your merits. You stand here among friends and well-wishers, to all of whom you are well known as the capable Assistant Secretary of the Society. But perhaps it is to the Council alone, and more particularly to

those who have served as Officers, that the full extent of the indebtedness of the Society to you is known. You combine the offices of Assistant Secretary, Clerk, Librarian, Editor of the Journal, and Curator of the Museum, and each of these offices, whether the duties are performed by you personally or under your general supervision, is filled to the great advantage of the Society. Authors of papers owe you a deep debt of gratitude for the help that they have received from you in editing their papers; indeed, such trust have they in your judgment, that they are almost too liable to leave the whole of the burden of seeing their papers through the press in your hands.

If it were necessary for me to allude to actual geological work done by you, I have only to mention the Index to the first Fifty Volumes of the Quarterly Journal, which was completed by you outside your official hours, and has proved of immense value to all writers in geology. But in handing you this award of the Wollaston Donation Fund, I trust rather that you will receive it as a mark of appreciation by the Council and Fellows of your able and conscientious services to the Society and to geology as Assistant Secretary and Editor of the Journal, and I can only conclude with the hope that we may have the advantage of your services for many years to come.

Award of the Murchison Geological Fund.

The President, in handing the Balance of the Proceeds of the Murchison Geological Fund, awarded to Mrs. Elizabeth Gray, of Edinburgh, to Dr. Henry Woodward, F.R.S., for transmission to the recipient, addressed him in the following words:—

Dr. Woodward,—

Mrs. Gray has devoted the leisure-hours of nearly half a lifetime to collecting in the field and arranging in her cabinets the fossils of the Ordovician and Silurian rocks of the Girvan district of Ayrshire. The palæontology bears so closely on the structure of this complicated region, that a detailed knowledge of it is indispensable to any geologist who attempts to unravel that structure.

Her collections have been of more than ordinary value, because of the careful record that she has kept from the first of the exact locality and horizon at which each fossil was collected. She has generously placed her specimens at the disposal of all geologists and palæontologists engaged in the study of the Palæozoic rocks and fossils, and a large number of them have been described in the monographs of Davidson, Nicholson, Etheridge, and others. When working in the Girvan district, the officers of the Geological Survey of Scotland checked their own collection by that of Mrs. Gray, and paid a well-earned tribute to its value by publishing in their Memoir on the Silurian Rocks of Southern Scotland a full list of all her fossils, supplementary to their own. My own personal indebtedness to the collections made by Mrs. Gray and her family, when I was working at the geology of that district, was especially great; and it affords me no ordinary gratification to be able to hand to you, for transmission to her, the Balance of the Proceeds of the Murchison Geological Fund, on behalf of the Council of this Society.

Dr. Woodward, in reply, read the following letter which had been forwarded to him by the recipient:—

'Dear Dr. Woodward,

'I am gratified to learn that you intend to be present at the Anniversary Meeting of the Geological Society, and I thank you for your kindness in allowing me to nominate you to receive for me on that occasion the Murchison Fund, awarded by the Council of the Society in consideration of what you too generously characterize as "great services to Geological Science."

'My work in the Girvan district, among the fossils of the Silurian rocks, has been to me a lifelong pleasure, augmented of late years by the knowledge that my collection has proved of service to the Geological Survey of Scotland, as well as to individual geologists—to name among these but the late Dr. Thomas Davidson.

'It is incumbent on me, however, to record that my husband, the late Mr. Robert Gray, taking a keen interest in my pursuits, shared with me during many years the agreeable task, not only of searching for fossils, but of helping to work them out when found, so that it is difficult for me, in the present circumstances, to repress a pang of regret that he cannot likewise participate in my satisfaction at the Geological Society's very gracious recognition of what, to some extent, was our joint work.

'I value very highly the honour conferred upon me, and beg you to convey to the Council my grateful thanks and sincere acknowledgments.'

Awards from the Lyell Geological Fund.

The President then presented part of the Balance of the Proceeds of the Lyell Geological Fund to Mr. George Edward Dibley, addressing him as follows:—

Mr. Dibley,—

You have, for a number of years, devoted the leisure-hours of a busy life to the careful collecting of fossils from the Chalk, and have thereby added much to our knowledge of the distribution of species in the several life-zones. The results of these labours have been partly published in the Proceedings of the Geologists' Association, and they include the record of the discovery of a specimen of especial interest, as it is believed to be a representative of the lizard-like Rhynchocephalia, no example of which has been previously recorded from the Chalk.

I have much pleasure in handing to you a moiety of the Balance of the Lyell Geological Fund, which has been awarded to you by the Council of this Society.

Mr. Dibley replied in the following words:—

Mr. President,—

I beg to thank the Council of the Geological Society most heartily for their kind appreciation of my efforts to further the accurate knowledge of our Cretaceous geology by the systematic and patient collecting of fossils zone by zone, a method of research so clearly demonstrated by you, Sir, in the older Palæozoic rocks. I can assure you that it is a delight to me to be able to devote each week-end to this branch of natural science; and I only trust that I may be spared to continue my labours on new ground as well as on the old, so that I may be of further use in promoting the advance of geological science.

I may perhaps be allowed to add that, in thanking you for this honour conferred upon me, it gives me especial pleasure to receive it at your hands.

The PRESIDENT in handing the remainder of the Balance of the Proceeds of the Lyell Geological Fund, awarded to Mr. SYDNEY S. BUCKMAN, to Dr. F. A. BATHER, M.A., for transmission to the recipient, addressed him in the following words:—

Dr. BATHER,—

In the year 1897 the Council of the Geological Society awarded to Mr. Buckman the proceeds of one of their Funds, in acknowledgment of the important work which he had already accomplished among the Jurassic Invertebrata, and of his investigations into the stratigraphical details of the Jurassic formations, expressing their confidence that he would be certain to continue and extend that work.

Their confidence has been more than justified; for, since that time, not only has he issued important supplements to his Monograph on the Inferior Oolite Ammonites, published by the Palæontographical Society, and continued his stratigraphical studies on Dundry Hill, and on the Bajocian and Contiguous Deposits in the Northern Cotteswolds, but he has broken new ground in his memoir on 'Homœomorphy among Jurassic Brachiopoda,' that will doubtless have far-reaching results. He has also published interesting and suggestive papers upon river-development, especially with regard to the genesis of the Severn and the Wye.

For a quarter of a century he has devoted his energies and genius to the advance of geology and palæontology, and each year he has presented to science something valuable and original. The Council of the Geological Society, while sensible of the inadequacy of this recognition of his labours, hope that he will accept it as an earnest of their appreciation of his scientific work.

Dr. BATHER, in reply, said:—

Mr. PRESIDENT,—

In receiving this Award on behalf of my friend, Mr. Buckman, it had not been my intention to depart from the precedent that commends silence to the recipients of funds as the most suitable expression of their gratitude; in fact, I took care to leave at home the speech that he wrote out for me. But, since this somewhat recent precedent has twice been broken this afternoon, I might seem

wanting, both in courtesy to yourself and in loyalty to Mr. Buckman, if I did not give the gist of his remarks.

Mr. Buckman is aware that his palæontological work, especially that relating to Ammonites, has met with considerable criticism. He is therefore particularly grateful for this recognition on the part of the Council of the Geological Society. The principles that have animated his work on the Ammonites have been applied by him also to the Brachiopods. They are, in fact, principles that are working a vast revolution in the whole of palæontology. The interpretation of the phenomena of homœomorphy—that is to say, the appearance of species, at the same or different periods, perplexingly similar in outward form though descended from different stocks—will lead to much more exact identification of fossils. This preciser palæontology, in conjunction with field-work among the Secondary rocks on the lines indicated in Mr. Buckman's last paper contributed to this Society, will, he is confident, have a distinct practical value, since it is bound to throw light on the position of concealed coal-basins. Unfortunately, such wealth as may be obtained in consequence of this purely scientific research will, under present laws, fall not to the nation but to landowners: least of all will the students, to whose researches it is due, receive any material benefit—except, perhaps, such an Award as this, for which I have to offer to you, Sir, Mr. Buckman's sincere thanks.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT,
Prof. Charles Lapworth, LL.D., F.R.S.

Our ranks have been thinned during the past year by many widely-deplored losses. To some of these I will now refer.

Prof. Alpheus Hyatt, Foreign Correspondent of the Geological Society, died at Cambridge (Mass.), on January 25th, 1902, in his 64th year. Outside of his many valuable publications in pure zoology, Prof. Hyatt's chief reputation will largely rest on his researches in the field of organic evolution. Perhaps no other American contributed so much towards the discovery of the laws of development and growth, and to an exposition of the exact methods of research in evolutionary problems. The principles that he enunciated constitute the foundation of a young and vigorous school of evolution, which is already making itself felt in the scientific world.

He was born in 1838, and he completed his freshman year at Yale with O. C. Marsh in 1856. He then travelled for a year in Europe, and afterwards entered the Lawrence Scientific School at Harvard, graduating in 1862. He served for nine months during the Civil War. Later he renewed his studies with Prof. Louis Agassiz, and subsequently became intimately identified with all the scientific interest centreing about Boston. He had official connection with the Essex Institute, the Peabody Academy of Science, the Laboratory of Natural History at Annisquam, the Massachusetts Institute of Technology, Boston University, the Museum of Comparative Zoology, the United States Geological Survey, and the Boston Society of Natural History, of which he had been Curator since 1881. In 1869 he was elected a Fellow of the American Academy of Arts & Sciences, and in 1875 a Member of the National Academy of Sciences. He was a member of many other societies at home and abroad, and was elected a Foreign Correspondent of our own Society in 1897.

His various publications include:—Observations on the Polyzoa (1866), Fossil Cephalopoda of the Museum of Comparative Zoology (1872), Revision of the North American Poriferæ (1874–77), Genesis of the Tertiary Species of *Planorbis* at Steinheim (1880), Genera of Fossil Cephalopoda (1883), Larval Theory of the Origin of Cellular Tissue (1884), Genesis of the Arietidæ (1889), Phylogeny

of Acquired Characteristics (1895), and numerous essays on the stages of growth and decline in animals and on the various laws and problems of Evolution.[1]

Major John Wesley Powell, who had been elected a Foreign Correspondent of the Geological Society in 1892, died on September 23rd, 1902, at the age of 68. He was one of the foremost workers in science in the United States during the last half-century. Though of English parentage, he was brought up entirely in America. While young, he acquired an interest in scientific pursuits, and paid much attention to natural history studies. He made various expeditions and voyages on the Mississippi, Ohio, and Illinois rivers for the purpose of collecting specimens. But his scientific studies were interrupted by the Civil War, in which he took an active part, losing his right arm in an engagement. At the close of the war he received the rank of Major.

In 1865 he became Professor of Geology and Curator of the Museum at the Wesleyan University of Illinois, and later at the Illinois Normal University. In 1867 he organized a geological excursion to the mountain-region of Colorado. This was the beginning of his active work in the West, which led to such important discoveries in geology, geography, and ethnology. His second, and more important expedition wintered west of the Rocky Mountains, and Powell's attention was turned to the scientific study of the Red Indians, with which his name became afterwards intimately connected. In the following spring he organized an expedition to the cañons of the Green and Colorado Rivers. The entirely successful result of this expedition made Powell's reputation, and led to the organization, under the U.S. Government, of a Geographical & Geological Survey which was also to collect ethnological data. For ten years, from 1869 to 1879, he was occupied with this survey, the work being in course of time extended to the investigation of irrigation and water-supply. Then, at his own suggestion, his Survey was amalgamated with that of Hayden, King, & Wheeler, the result being the creation of the present U.S. Geological Survey, with Clarence King as the first Director, Powell being Director of the Bureau of Ethnology, created at the same time. On King's resignation in 1881, Powell succeeded him, and retained the Directorship for both Geology and Ethnology until 1894, when he gave up his geological work. During

[1] For the above particulars the writer is indebted to Am. Journ. Sci. ser. 4, vol. xiii (1902) p. 164.

his Directorship he thoroughly organized the U.S. Geological Survey, and placed it on that broad and satisfactory footing which it has since retained.

Major Powell received the degree of Ph.D. from the University of Heidelberg in 1886, and in the same year that of LL.D. from Harvard College. He was a member of many learned and scientific societies, and he became a Member of the American Association for the Advancement of Science in 1875, its Vice-President in 1879, and President in 1887.

His publications embrace many scientific papers and addresses, and numerous Government volumes, including Reports of various Surveys of the Bureau of Ethnology and the U.S. Geological Survey. The special volumes which bear his own name are 'Explorations of the Colorado River of the West & its Tributaries,' 1875; 'Report on the Geology of the Eastern Portion of the Uinta Mountains,' 1876; 'Report on the Lands of the Arid Region of the United States,' 1879; and 'Introduction to the Study of Indian Languages,' 1880. [Geogr. Journ. vol. xx (1902) p. 663.]

Arthur L. Collins was born on July 8th, 1868, at Truro (Cornwall), and received his training in mining and metallurgy under the supervision of his father, Mr. J. H. Collins, F.G.S. While young he went to Spain, and became assayer at one of the mines near the Rio Tinto; returning later on to Cornwall, where he became assistant superintendent of a tin-mine. From England he went to Norway to take charge of a zinc-mine, and in 1892 he was appointed chief geologist and mineralogist to the Amir of Afghanistan, a post which he held until 1894. In that year he went to America, to take charge of mines in Colorado. Between 1894 and 1902 he visited many other parts of the world on professional business, eventually returning to Colorado, where he was shot by an unknown assassin on November 19th last. He had been elected a Fellow of the Geological Society in 1892.

William Gunn, who had been a Fellow of this Society since 1876, was born on September 27th, 1837, at Wheatley, Cuddesdon, near Oxford. Before joining the Geological Survey in 1867, he spent several years in teaching, and during his leisure-moments developed his knowledge of geology and botany. The first half of his official career was occupied in mapping large areas of the six northern counties of England, where he acquired an intimate

knowledge of the Lower Carboniferous rocks, and of their gradual modification as they are followed northward into Scotland. For many years geologists experienced some difficulty in correlating the subdivisions of that system in the two countries. But the careful tracing of the respective zones from Yorkshire northward to Berwick, in which Mr. Gunn had a prominent share, threw important light on the subject. Indeed, his paper on 'The Correlation of the Lower Carboniferous Rocks of England & Scotland,' published in the Transactions of the Edinburgh Geological Society for 1898, is one of the leading contributions to the study of this question.

In 1884, Mr. Gunn was transferred to Scotland, where he displayed marked power in dealing with questions of complicated stratigraphy. He took part in the detailed mapping of the North-Western Highlands, and he surveyed Arran, Bute, the Cumbraes, and part of Cowall. Nowhere did he display his power as a field-geologist with greater success than in Arran, that paradise of Scottish geologists. His complete demonstration of the unconformity between the red sandstones, now known to be of Triassic age, and all older formations in the island, and his identification of volcanic rocks ranging from the schistose rocks of the Highland Border to those of Tertiary time, are sufficient testimony of his powers of accurate observation and sound reasoning.

Mr. Gunn was author of memoirs published by the Geological Survey on Belford, Holy Island, and the Farne Islands, on the coast south of Berwick, on Norham and Tweedmouth; and he was joint author of memoirs on Wooler and Coldstream, on Ingleborough, and on Cowall in Argyllshire. Before his death he was engaged in finishing the proof-sheets of the memoir on 'The Geology of Central & Northern Arran,' and the manuscript relating to the southern part of that island.

In 1884 he was promoted to the rank of Geologist; in 1901 to that of District-Geologist. He retired on September 27th, 1902, and died a few weeks later, on October 22nd. [J. H.]

Alfred Vaughan Jennings was born in 1864, and was educated at St. Paul's School, and at the Normal School of Science and Royal School of Mines, now the Royal College of Science, London. Here he soon distinguished himself by his work in natural history and geology, and was appointed Assistant in the Geological Laboratory, under Prof. J. W. Judd. His health was, unfortunately, at no time good, and this led him to resign his appointment in 1889.

After a voyage to New Zealand, where he made some botanical observations, he returned to teaching-work in London, mainly in connection with the Birkbeck Institution. Several of the students who here came under his influence have since become known for their researches in zoology and palæontology. Mr. Jennings also played a conspicuous part in the organization of the Museums at Eton College and in Whitechapel. In 1895 he joined his former colleagues, Profs. Cole and Johnson, at the Royal College of Science, Dublin, and acted as Demonstrator in Botany & Geology until 1898. He had meanwhile become a Fellow of this Society in 1891.

Mr. Jennings's first geological paper was on the 'Orbitoidal Limestone of Northern Borneo,' published in the Geological Magazine for 1888. In the following year he worked with Prof. Cole on Cader Idris, and in 1890 with Mr. G. J. Williams in the Moelwyn area. The results of these observations appeared in our Quarterly Journal, where they were followed by two papers, in 1898 and 1899, on the Davos district of Switzerland. The latter of these dealt in some detail with the structural features of that region of the Alps. Mr. Jennings also contributed papers on river-courses near Davos, and on Bad Nauheim, to the Geological Magazine; and in 1900 the Council of this Society awarded to him the balance of the proceeds of the Murchison Geological Fund. He was also a Fellow of the Linnean Society, and author of papers on both botany and zoology.

Mr. Jennings travelled frequently in various countries of Europe, and made scientific friends in every centre where he stayed. He died at Christiania (Norway) on January 11th, 1903, and the Geological Club of Christiania, in laying a wreath upon his coffin, paid a graceful and kindly tribute to a deceased fellow-worker. The memory of his skill as a teacher, and of his absolute precision in all the details of his work, will long remain with his colleagues.

[G. A. J. C.]

Joseph Landon was born at Draycote (Warwickshire). At the age of 10 he came with his parents to live at Birmingham, and eventually became a pupil-teacher. In 1865 he entered Saltley College as a first-class Queen's Scholar. On the completion of his training he served as second master in the Central School of Stoke-upon-Trent, and was subsequently made Master of Method at Saltley Training College. In this capacity he was very successful, and was sent on a visit to the various Training Colleges of Great Britain, to report on the systems of teaching then in vogue. He

was, moreover, the author of two works upon the subject of school-management, which have run through several editions. In 1893 he was appointed Vice-Principal of the Saltley College, a post which he held until the time of his death.

In scientific work, especially in geology, he took an active interest. He was prizeman in the geological classes at the Mason College two years in succession, and became a Fellow of the Geological Society of London in 1887. He entered into research-work in geology with great keenness, and proved himself a good stratigraphist. He mapped in person part of the Permian of South Staffordshire, and was the first to discover the existence of Lower Bunter Beds on the east side of the South Staffordshire Coalfield. He paid also especial attention to the distribution and contents of the river-gravels of the Rea, near Saltley, obtaining implements characteristic of early man, and his work in this direction has been referred to by Sir John Evans and others in complimentary terms. He died on November 7th, 1902.

Don José Macpherson, who died at Madrid on the 11th of October last, was born at Cadiz in the year 1839. He was the son of a wealthy Scotsman and a Spanish lady, and united in his life and character British patience and doggedness with Andalusian brilliance and geniality. His education was begun at Gibraltar, and even at an early age he showed himself superior to the attractions of such a life of ease and social enjoyment as his father's means might have allowed him to lead.

His first studies were directed to mathematics, physics, and chemistry, especially the last-named. These he studied in Paris, following the lectures of the most eminent professors in that metropolis, and working diligently in their laboratories. He next conceived a great enthusiasm for mineralogy, and studied for some time under the celebrated Pisani, becoming especially expert in the determination of mineral species. Returning to Cadiz and Seville, he published in 1870 his first work, 'On a Method of Determining Minerals.'

He soon, however, went back to Paris, and, after making various excursions with Daubrée, Stanislas Meunier, and others, he concentrated all his attention upon geology. He travelled through Switzerland, climbing its mountains and studying its glaciers, and thence returned to Spain, where he at once commenced the examination of its geology. The first fruits of this work were presented

to the public in his 'Geological Sketch of the Province of Cadiz,' published in 1872, a memoir which at once attracted the attention of scientific men on account of its breadth of treatment.

In 1874 Macpherson took up his residence at Madrid, where he built later on his little mansion in the Calle de la Exposicion, which under his fostering care became a sort of geological institute, for the use of himself and his friends. Here he lived for many years, making, however, annually excursions into foreign lands. He became a member of nearly all the Geological Societies of Europe (being elected a Fellow of our own Society in 1890), and belonged to some of those of Geography and Natural History; but he never occupied any official post, or accepted any titles or honours of any kind, except that of President of the Spanish Society of Natural History, and that of Corresponding Member to the Institute of France.

Of stratigraphical papers of the ordinary type Macpherson wrote few. The most important was one 'On the Geology & Petrography of the Province of Cadiz,' published in 1878, and another on the 'Stratigraphical Succession of the Archæan Rocks of Spain,' published in 1884.

On the orogenic side of geology Macpherson was an enthusiast, following along the same general lines as Dana, Suess, and their colleagues and sympathizers. His first paper on the subject was published in 1878, 'On the Dynamic Phenomena which determine the Special Structure of the Serranía de Ronda'; and this was followed in 1879 by his brief note concerning 'The Special Structure of the Iberian Peninsula.' Not only was he a pioneer in orogenic work in Spain, but we owe to him a large part, if not almost the whole, of what is known and has been quoted up to the present time concerning the structure of the Peninsula. In 1880 he published his paper 'On the Predominance of Uniclinal Structure in the Iberian Peninsula'; in 1886 his memoir on 'The Relation between the Forms of the Coasts of the Iberian Peninsula, the Principal Lines of Fracture, and the Sea-Bottom'; and the conclusions embodied in these he extended in two succeeding papers published in 1888. In his very last memoir—an essay 'On the Evolution of the Iberian Peninsula,' which appeared in 1891—he summarized the results of his own personal investigations, made in many a toilsome journey across his native land, and synthetized his broad and original views as to its geological structure and history.

Macpherson was hardly less interested in dynamic geology, although he published very few papers dealing with that branch of the science;

but there are abundant references, showing his grasp of the subject, interspersed throughout his geological papers generally. He discovered evidences of glacial action in the district of the Sierra de Guadarrama, etc. He was much interested in the subject of earthquakes, assigning them generally to orogenic causes.

On the side of palæontology Macpherson did but little; yet one important palæontological discovery must be credited to him, namely, that of *Archæocyathus* in the rocks of the province of Seville, which established for the first time the Cambrian age of those beds.

He was the first to introduce modern methods of petrography into Spain; he made his own slides, and was an adept in the use of the petrological microscope. His house was truly a combined petrological laboratory and geological lecture-room, open to the use of all who cared to learn. Among his petrological papers may be mentioned those on 'The Peridotitic Origin of the Serpentines of the Serranía de Ronda,' 1875; 'The Eruptive Rocks of the Province of Cadiz,' 1876; 'Petrological Descriptions of the Archæan Rocks of Galicia,' 1886, and of Andalusia, 1887; 'The Teschenites of Portugal & the Ophites of Andalusia,' 1889. His last paper in this department, on the subject of 'Molecular Motion in Solid Rocks,' was published in the year 1890.

To all this he added a keen interest in the science of meteorology, in which he made many important observations.

Macpherson was an enthusiast and an expert in the photographic art, not only in ordinary photography but also in telephotography. He took countless photographs of landscapes and structures eminent for their geological and archæological bearing, and presented them freely to those who were interested in these subjects.

The scientific lifework and output of Macpherson were great, both in extent and in depth. Nearly all the various branches of geology received his attention. He took up in turn and published papers on mineralogy, petrography, orogenic geology, and dynamic geology. His life was devoted to the pursuit of science for the sake of science; but the absolute scrupulosity and veracity which forbade him to modify in the minutest particular the results of his work in order to bolster up his theories, and forbade him at the same time to conceal any fact which might affect those theories adversely, rendered his literary style somewhat obscure, so that his published writings do not give us a true idea of his real scientific personality. In speech, however, he was clear and concise, and so enthusiastic in expression that his influence among Spanish geologists was deep and well founded. His reputation also was very great

among geologists in France and on the Continent generally; and British scientific men, who knew and valued his work, were wont to reproach him for not writing in English—a language with which he was so familiar—and publishing his results in London.

In Macpherson the man equalled the scientific worker. Generous to a fault, all that he possessed was at his friends' disposal. His conversation was always of an elevated tone, and never included personal blame of anyone. Modest, and a foe to all ostentation, he presented a remarkable union of gentleness with masculine vigour. It was impossible to approach him without feeling the magnetic attraction of an irresistible sympathy, and the ardent wish to enter into relations of cordial and affectionate friendship with him.[1]

[L. L. B.]

John Clavell Mansel-Pleydell was born in 1817, and educated at St. John's College, Cambridge. In 1863, on the death of his father, he succeeded to the family estate of Whatcombe near Blandford (Dorset), and to landed property in the Isle of Purbeck. Being an enthusiastic naturalist, he devoted much of his time to the botany, zoology, and geology of Dorset, and was the chief founder and supporter of the county Natural History & Antiquarian Field-Club. He became a Fellow of this Society in 1857. He contributed to the Geological Magazine in 1873 a 'Brief Memoir on the Geology of Dorset,' and to the Dorset Field-Club he communicated several papers on local geology, notably one on the occurrence of remains of *Elephas meridionalis* at Dewlish. He was also instrumental in obtaining many fine saurian remains from the Kimmeridge Clay, some of which were described by Owen and Hulke. He published separate volumes on the plants, the birds, and the mollusca of Dorset, and maintained his interest and enthusiasm in science until the last. He died on May 3rd, 1902. [H. B. W.]

William Henry Penning was born on March 9th, 1838, and was trained as a civil engineer under the late C. H. Gregory. He joined the staff of the Geological Survey in 1867, and was engaged in mapping the districts around Bishop's Stortford, Cambridge, and Lincoln until 1882, when he retired from the service on account of ill-health. The results of his official work were published in conjunction with the work of his colleagues, in the Memoirs on 'The Geology of North-Western Essex' (1878), 'The Geology of the

[1] For these particulars the writer is indebted to the biographical memoir published by Señor Calderón in 'Nuestro Tiempo' for November 1902.

Neighbourhood of Cambridge' (1881), and 'The Geology of the Country around Lincoln' (1888).

Mr. Penning became a Fellow of this Society in 1868, and in 1875 he communicated to it 'Notes on the Physical Geology of East Anglia during the Glacial Period.' He considered that the Glacial Drift was formed during a period of submergence, and that the Chalky Boulder-Clay was deposited in a more open sea than the earlier drifts. On the subsequent upheaval of the land certain 'denudation-gravels' were formed, and to these he drew special attention. He also wrote a small text-book upon 'Field-Geology.'

On leaving the Geological Survey, Mr. Penning spent some time in South Africa, where he regained his health, and was enabled to bring before this Society in 1884 a paper on the 'High-level Coal-fields' of the Transvaal and bordering what was then the 'Orange Free State.' In the following year he gave us 'A Sketch of the Goldfields of Lydenburg & De Kaap,' and in 1891 'A Contribution to the Geology of the Southern Transvaal.' He died on April 20th, 1902. [H. B. W.]

Philip James Rufford, the only son of the Rev. Philip Rufford, was born at Great Alne (Warwickshire) in 1852. He was brought up as a civil engineer, but early in his career his health broke down, and he was compelled to abandon his profession. About the year 1888 he settled at Hastings. He had already acquired a very considerable knowledge of geology, and set to work to collect fossils from the Wealden strata of the neighbourhood. He obtained eventually a fine collection of Wealden plants, which are now in the Natural History Museum, South Kensington, and 147 specimens of these have been described by Mr. Seward.

The Museum of the Brassey Institute, Hastings, of the Committee of which Mr. Rufford was a member, purchased part of the Beckles collection of Wealden and other fossils. He selected, named, and arranged these for the Museum; and year after year added largely from his own private cabinet to the palæontological section of the Museum, in which until the day of his death, in 1902, he took the greatest interest. His loss will long be deeply felt by the Museum and by all his colleagues. He had been elected a Fellow of the Geological Society in 1899. [H. W.]

Alfred Charles Selwyn, C.M.G., LL.D., F.R.S., who was elected a Fellow of this Society in 1871, died at Vancouver (British Columbia), on October 19th, 1902.

He was born at Kilmington (Somerset), on July 28th, 1824, and was educated in Switzerland, where he acquired a taste for geology. At the age of 21, that is, in 1845, he received an appointment on the field-staff of the Geological Survey of Great Britain under Sir Henry de la Beche and Sir Andrew Ramsay; and with the latter, with Aveline, Jukes, Howell, Phillips, Smyth, and others, contributed much to our knowledge of the geological structure of North Wales and the adjacent portions of Western England. He is credited with no less than sixteen geological maps, prepared either entirely by himself or in conjunction with his colleagues.

In 1852 he accepted the position of Government Geologist to the Colony of Victoria (Australia), and for 17 years he acted as Director of the Geological Survey of that colony. His training in the older Palæozoic rocks of Wales was of especial value to him in his new sphere of action; and accordingly he set himself the task of mapping out the gold-bearing rocks and gravels of different ages, and in tracing their relations to other rocks of the district. Here, however, he had a field of work nearly twelve times greater than he had had in Wales. During his period of office Selwyn, besides issuing an extensive series of geological maps of Victoria, prepared numerous reports and papers bearing more especially upon the economic resources of Australasia.

In 1869 Selwyn was called upon to succeed Sir William Logan as Director of the Geological Survey of Canada, a position which he held for twenty-five years. This period was one of great activity in the Canadian Survey, no less than twenty large volumes of Annual Reports, with accompanying maps and sections, being issued, in addition to other works, palæontological memoirs, etc. Notwithstanding the arduous administrative duties which Selwyn was called upon to fulfil in planning out the work to be carried on by his staff, and arranging all matters relating to the expenditure of the grant allowed by the Canadian Government, as well as in editing the reports of his assistants and writing his own, he yet found time to traverse and personally explore large extents of unmapped territory.

In addition to these duties, the Dominion Government requested Dr. Selwyn to act as Assistant to the Canadian Commissioners at the Centennial Exhibition held in Philadelphia in 1876, at the Paris Universal Exhibition in 1878, and at the Colonial & Indian Exhibition in London in 1886; these appointments involved an enormous amount of labour, and included the preparation of

descriptive catalogues of the economic minerals and notes on the rocks exhibited in the Canadian Court on each occasion.

In 1871, Dr. Selwyn was elected a Fellow of the Geological Society of London, and in 1874 a Fellow of the Royal Society. In 1876 he was awarded the Murchison Medal by the Council of the Geological Society, 'in recognition of his services to Silurian geology.'

First, and foremost, Selwyn was a stratigraphical geologist. His career was one full of usefulness to the Empire. He wrought successfully in the motherland, and also in two of her most prosperous colonies. His chief work in the three continents lay among the older Palæozoic and Archæan rocks. He paid special attention to the pre-Cambrian volcanic rocks in the Eastern Townships of Quebec, and was the first to decipher the geological structure of the eruptive axes in Eastern Canada. His classification of pre-Cambrian rocks made in 1877 is practically that adopted now by recent investigators. He always emphasized the economic side of the science of geology without, however, ignoring the claims of original research. He did much to encourage those under him to study and solve the problems of complex geological structure or of chronology which presented themselves to him in his official labours.

In the office, Selwyn was a strict disciplinarian. A love of order and neatness seemed to be one of his leading characteristics, and in the reports and work that he received from the staff he demanded the same. But the more stern and severe official side of his nature was in marked contrast with the sociable, amiable, and chivalrous qualities which distinguished him in his own home.

[H. M. A. & H. W.]

Francis Stevenson, who died at the advanced age of 74 in February 1902, had become a Fellow of the Geological Society in 1877. His career was a notable one. He was born of an old Scottish family in 1827, and after receiving his education at the Edinburgh Academy, was, at the early age of 13, articled as a pupil to the late Mr. R. B. Dockray (then one of the engineers of the London & Birmingham Railway Company), becoming in 1843 a member of the engineering staff. He was engaged on the construction of the Northampton & Peterborough line, which was opened in 1845, and was also resident engineer on the Coventry & Nuneaton Railway, completed in 1850. Subsequently he was transferred to Euston Terminus, and in 1855 became assistant to the

late Mr. Baker, whom he succeeded as chief engineer, in charge of all new works and Parliamentary business, in January 1879. He died literally in harness, after a devoted service of nearly 59 years.

He always took a keen interest in geology, and his geological knowledge was of much service in dealing with the many important schemes entrusted to his judgment. He was an ardent lover of Nature, with a profound veneration for ancient and historical buildings, and when designing new work he was careful so to arrange his designs that they should leave, as far as practicable, undisturbed any prominent or pleasing feature in the vicinity. He was a Member of the Institution of Civil Engineers.

The Rev. THOMAS WILTSHIRE was born in the City of London on April 21st, 1826. He was educated at home by a private tutor, and afterwards commenced as a student at King's College, London; but at the age of 19 he entered Trinity College, Cambridge, where he did well in classics and mathematics. Here, attending Sedgwick's lectures, he acquired a taste for geology, which continued to be the dominating pursuit of his leisure-hours in after-life. He took his B.A. degree with honours on January 26th, 1850, and in the following June was ordained a deacon and became Curate of Riddings (Derbyshire). He took his M.A. degree in July 1853, and on the 18th of December of that year was ordained a priest.

For many years he spent his summer holidays at Folkestone, where he assiduously collected the fossils of the Gault and the Grey Chalk, assisted in his labours by Griffith, the well-known collector. In other years he stayed at Niton and Ventnor, in the Isle of Wight, collecting from the Hard Chalk, Chloritic Marl, and Upper Greensand with Mr. Mark Norman; or working at the Red Chalk of Hunstanton with Westmoreland, the old lighthouse-keeper, or at the Chalk of Filey, in Yorkshire. From these historical localities, either with his own hands or aided by the local collectors, and likewise from that well-known old explorer of the Upper Chalk of Bromley (Kent), Jeremiah Simmonds, Mr. Wiltshire gradually accumulated a very fine collection of Cretaceous fossils, which about five or six years ago he presented to the Woodwardian Museum, Cambridge, where they are now preserved.

In 1856 Mr. Wiltshire was elected a Fellow of the Geological Society of London, and in 1859 he was elected President of the newly-formed Geologists' Association, in succession to Toulmin Smith, its first President. On April 4th, 1859, he read before it

an excellent paper on the 'Red Chalk of England.' Mr. Wiltshire remained President of the Association from 1859 to 1862, and was re-elected to the same office from 1871 to 1873. In January 1862 he read a second paper to the Association, 'On the Ancient Flint-Implements of Yorkshire, & the Modern Fabrication of Similar Specimens.'

His friend Bowerbank relinquishing the Secretaryship of the Palæontographical Society in 1863, Mr. Wiltshire was appointed in his stead. He held the office of Secretary until 1899, a period of thirty-six years. He was also elected Secretary of the Ray Society in 1872, and continued to hold that post up to the time of his death. On his retirement from the Secretaryship of the Palæontographical Society, the two Societies presented him with an illuminated address, his portrait in oils, and a cheque.

From his first home in Brompton he removed with his family to the Rectory, Bread Street Hill, E.C., in 1864. There he remained until about 1869, when, on its demolition for City improvements, he migrated to Lewisham, where he resided up to his death. From 1872 to 1880 he acted as Lecturer in Geology for Prof. Tennant at King's College. In 1880 he filled the office of Dean for Evening Instruction; on Tennant's death in 1881 he was appointed Assistant-Professor, and in 1890 Professor of Geology and Mineralogy, a post which he held until 1896, when, upon his retirement, he was duly elected a Fellow and Emeritus Professor of King's College.

Mr. Wiltshire was elected one of the Honorary Secretaries of this Society in 1874, an office which he filled until 1878. In 1882 he was elected Treasurer to this Society, a post which he continued to hold until 1895, a period of thirteen years.

After Mr. Wiltshire ceased his geological work, he spent his vacations in visiting Algiers, Iceland, Norway, and the Swiss Alps. In Switzerland, indeed, he spent several of his long summer-vacations. On four occasions he went to North America, visiting Canada, the United States, the Yellowstone Park, and the Rocky Mountains. On April 27th, 1899, the University of Cambridge conferred upon him the honorary degree of Doctor in Science.

The Rev. Dr. Wiltshire performed the service, and delivered his last Sunday-evening lecture at St. Clement's, Eastcheap, on October 26th, 1902, returning home cheerfully to supper, his duty ended. The same night he passed quietly away, after a busy life of 76 years. [H. W.]

Baron HENRY DE WORMS, first LORD PIRBRIGHT, who was elected a Fellow of this Society in 1861, died in January 1903 at the age of 63. He was born in 1840, and was the third son of Solomon Benedict de Worms, Hereditary Baron of the Austrian Empire. He was educated at King's College, London, of which he became a Fellow in the year 1863. He was at first intended for the medical profession, but entered as a student at the Inner Temple in 1860. His collegiate career was one of more than ordinary distinction, as he was a good classical scholar, and possessed a mastery of several modern languages. He also attained proficiency in mathematics, and developed a taste for physical science. He devoted some time to the study of cosmology and the various phenomena attendant on the motion of the earth through space, giving the result of his speculations to the world in a work entitled 'The Earth and its Mechanism' in 1863. In 1885 he was appointed Parliamentary Secretary to the Board of Trade, and in 1888 he became Under Secretary for the Colonies, a post which he retained till 1892. In the same year (1888) he was made a member of the Privy Council, and in 1895 was raised to the peerage. Lord Pirbright resided in his later years mostly at Henley Park, Guildford.

THE RELATIONS OF GEOLOGY.

WE stand to-day, Gentlemen, at the beginning of a new century. The science of Geology, whose devotees we are, is one of the youngest of the great family of the sciences. The years since first it became conscious of its being are but few in number, and its struggle for existence has from the first been incessant. Yet I doubt not that there are many observers familiar with its history who would assert that 'young as it is in years, it is already old in achievements, and that the roll of its discoveries and the number and extent of its conquests stand almost unrivalled for their far-reaching influence upon the philosophy and the practice of mankind.'

But it is neither necessary nor dignified on our part here to-day to advance or even suggest this claim. For it is not our self-esteem which prompts our work, or the applause of the world that cheers us in its pursuit. Rather is it the delight in the work itself which animates our labours; and it is in the sympathy and the appreciation of our fellow-workers that we rejoice when our aim is achieved. To Geology and geologists do we stand or fall.

That being so, I have asked myself, as your elected representative, whether it would not be good for us, as a united family of geologists met here together at the close of one era and the opening of the next, to take stock, as it were, of the work which Geology has already accomplished, and note how we are prepared to face the tasks which the new era will demand of our science and of ourselves.

But self-centred though we may be as individual geologists, and self-centred though we may consider our science, we share the common lot of all men, and our science shares the common lot of all the sciences. As individuals we receive from our fellow-men all that makes for our social well-being; and our science owes its very existence, and most of the conditions that make for its progress, to the aid and sympathy afforded by its fellow-sciences.

We have, therefore, no right to make this prospect or retrospect in the family privacy of our own science, without regard to the feelings or the claims of others. Geology has not only its privileges but also its duties, and the entire world of science and practice has the right of demanding a justification of the faith that is in us. Nor do I think that it asks too much if it insists upon a categorical answer to the questions:—What is this Geology of which we are so proud and so confident? What has it done for the mental or material benefit of the human race? and on what grounds does it justify its claim to respect and support as one of the factors in the advance of humanity?

Far be it from me to presume to attempt to reply on your behalf to questions of so serious an import. That task must be left in part to the eloquent apologists of our science, and in part to the results achieved by the great workers in geology—results that carry the answer with them. But on an occasion like the present, I doubt whether we can do anything better or more appropriate to the time than have a quiet but open talk together over the position and relations of our science.

Geology and its Fellow-Sciences.

Geology and Astronomy.—In the words of one of the most devoted adherents of our science, we might say 'without impropriety, that all the physical sciences are included under two great heads—Astronomy and Geology: the one comprehending all those sciences which teach us the constitution, the motions, the relative places, and the mutual action of the Astra, or heavenly bodies; while the other

singles out for study the one Astrum on which we live, namely, the earth.'

This definition, if we may call it so, is one which is not only simple and convenient, but it gives perhaps the broadest and clearest view of the place and mission of Geology, regarded from an outside standpoint. And there is a naturalness in this association of Geology and Astronomy which cannot be ignored.

Astronomy concerns itself with the whole of the visible universe, of which our earth forms but a relatively insignificant part; while Geology deals with that earth regarded as an individual. Astronomy is the oldest of the sciences, while Geology is one of the newest. But the two sciences have this in common, that to both are granted a magnificence of outlook, and an immensity of grasp denied to all the rest.

Yet, compared with other sciences, few perhaps have so small a number of adherents and working members. It may be that this is due to the opinion of the majority both of the past and the present generation, that these two sciences seem to demand for their successful prosecution an abnegation of emotion and of all human sympathies: their grandest results are not the conquests of the heart but of the head, wrought out in the cold dry light of reason.

It is needless in these days to insist upon the fierce and pained resistance which both have encountered at almost every fresh advance. In spite of the fact that in the end every such advance has proved itself to be a higher stage in the mental or material progress of mankind at large, there still exists, even at the present time, an instinctive antagonism to Astronomy and Geology in the minds of many, especially from the sides of literature and of philosophy.

The bewildering immensities of space and time with which these two sciences deal, and their insistent claim to be the only authorities that can bring home to the mind of man the awful ideas of infinity and eternity, cause them to be shunned and dreaded by the man of letters, and wring now and again a wail of impotence and sadness from the poet:—

> 'What be these two shapes high over the sacred fountain,
> Taller than all the Muses, and higher than all the mountain?
> On these two peaks they stand, ever spreading and heightening.'
>
> . . . .
>
> 'Look in their deep double shadow, the crowned ones all disappearing!
> These are Astronomy and Geology—terrible Muses!'

But while Astronomy and Geology share almost equally in the vague dread which they inspire in the minds of those who look only at Nature from the side of the emotional and the beautiful, they by no means share equally in the admiration instinctively accorded by the average thinking man to the sciences in general. Along the whole range of the concrete sciences, there is perhaps not one that has so effectually compelled the respect of men as Astronomy. There is not one in whose progress they have taken so keen an interest, or whose conclusions have been so unhesitatingly accepted. On the other hand, every new discovery arrived at by Geology appears to have come upon the minds of men with something of the nature of a shock. The conclusions of our science seem rarely or never to have been accepted with pleasure because of their value or their grandeur, but rather to have been adopted with reluctance and regret and because they were found to be irresistible.

Yet, after all, this is hardly a matter for astonishment, for it has its root in the origin and the growth of the two sciences themselves. Astronomy had its birth in the childhood of mankind, in the silence and calm of the night, and in the wonder of curiosity and awe. It carried with it from the very first the mystic fascination of the distant and unknown. It was associated in man's mind with the peaceful hours of rest and of contemplation. It held within it much of the enthusiasm and elevation of religion, for it lifted man's eyes upward and heavenward, away from the never-ending struggle in the world below.

Geology had none of these attractions. The world over which early man wandered was to him the theatre of a never-ending conflict, in which were arrayed against him impassable seas, unscalable mountains, gloomy forests peopled by deadly beasts of prey, raging streams and foaming torrents, each and all the haunts of spirits luring him to doom.

What wonder, then, that Astronomy was one of the first of the sciences to come into being, and that the successive generations of mankind have mingled with an awe of her greatness a tender and respectful appreciation of her work and of her results?

And it was but natural that Geology should be non-existent until long after most of the other sciences had come into being, and some had grown almost to maturity. Even when she at last appeared and thrust herself, as it were, into the established aristocracy of the sciences, she brought with her the stigma of her lowly origin. And to that she added much of the recklessness

and assurance of youth, and a bewildering absence of respect for the settled conventionalities of opinion and tradition. This is no excuse; but it is in its way a reason why she is still supposed to be somewhat of a *parvenue* among the sciences, and is often only listened to with patience because of her powers and her genius.

But there is also another reason for the reluctance with which the conclusions of Geology are received by men in general, when compared with the reception accorded to those of Astronomy:—namely, the relative backwardness of the race in its appreciation of the concept of the extension of time as compared with its advanced appreciation of the concept of the extension of space. Note the willingness, and even the welcome with which any average audience of the present day accepts the statements and sympathizes with the conclusions of an astronomical lecturer who demands for his remoter starry distances, it may be, myriads of millions of miles. Compare that reception with the coldness, or at all events the smiling incredulity, of the same audience when a geologist suggests for the development of all the geological formations at the very most a hundred millions of years. But it is not only the popular audience, but also the majority of the men of education and experience, who still feel this curious hesitation and difficulty. And nothing perhaps has so retarded the reception of the higher conclusions of Geology among men in general, as this instinctive parsimony of the human mind in matters where time is concerned.

Yet, after all, perhaps this is easily accounted for. It has been well said that 'the intellectual advancement of men is due to the relatively small effects of individual experiences added to the large effects of the experiences of the antecedent individuals.' The concept of the vastness of space has been familiar to mankind for untold ages, and has grown and expanded with the growth of the race. The concept of the immensity of time has entered so little into the intellectual development of mankind as a whole, and in its grander aspects so recently, that the race is as yet incapable of adequately grasping it.

The wanderings of early man from place to place and land to land soon familiarized him with the idea of the extension of space. He had learned by bitter experience times out of number that the distant horizon which to the eye bounded the vast canopy of the sky above him, was no boundary at all, but shaded away in all directions into a limitless world beyond, whose practical infinity had

been proved to him by his own wanderings, and by those of his forefathers generation after generation. Thus the idea of the vastness of space had already become a part of man's intellectual equipment long before the origin of Astronomy itself. And this idea has been deepened, broadened, and strengthened during the successive centuries of progress by the employment of constantly-improving instruments of accurate measurement, by the invention of the telescope, the discoveries of Geography, and by the application of the higher mathematics to Astronomy as a whole.

But early man (and indeed his successors even down to and beyond the Middle Ages) was miserably provided with the experiences which might bring home to his mind the immensity of time. Early man himself had for his longest trustworthy chronological base-line a short seventy years—the span of his own existence, —or at most perhaps a hundred years, if he included the experience of his parents. Even in classical times all the past was to his experience vague and indefinite. He had, it is true, mythical traditions of heroic ages, golden ages, and the like, but these when summed up were merely the legendary total of the experiences of but a few generations. Bound down as was man's mind by his anthropomorphic ideas, he naturally assigned to the earth and mankind a correspondingly brief existence; a few generations—a few centuries at the most—must have witnessed its birth; a few generations more must inevitably bring about its death and disappearance. Even since the invention of letters and the compilation of accurate historical records, the period of time of which man possesses experience, either personally or collectively, is at most a very few thousands of years. It is hopeless to expect, therefore, that for a long period to come the geological concept of the immensity of past time will permeate the minds of the many, or that they will accept the conclusions of Geology where time is concerned, with the same confidence as that with which they have long since accepted the conclusions of Astronomy.

But this intellectual backwardness of the race in the matter of the appreciation of the vastness of geological time is not only a stumbling-block in the way of the acceptance of the results of Geology among the public at large, but also to the workers in other sciences, and even to the students of Geology itself. It is well within the memory of many of us how even those holding the most advanced views in other sciences were intensely reluctant to acknowledge the possibility of the existence of man upon the earth for more

than a few thousands of years. And among the geologists of the preceding generation, the demand of the so-called 'uniformitarians' for those vast æons which must be granted, if the geological formations were accumulated and deposited at the same rate as corresponding accumulations are brought together at the present day, was only reluctantly conceded by the majority after years of conflict and denial. Even at the present time it is the habit not only of eminent physicists, mathematicians, and chemists, but also of some of our geological authorities, to scout all reasonings that suggest a geological antiquity for our globe of more than a few millions of years.

Far be it from me to suggest that geologists should be reckless in their drafts upon the bank of Time; but nothing whatever is gained, and very much is lost, by persistent niggardliness in this direction. The astronomer, although persuaded of the possible infinity of the universe, is just as careful in estimating the length of his grander base-lines of millions of miles as is the geographical surveyor who takes years, it may be, to measure accurately the length of a base-line a few miles in extent before he commences the triangulation of a single country. But the consciousness of the astronomer of the practical infinity of his realms gives him a freedom of action in dealing with space which is delightful. In the same way the geologist, who is blest with an assured conviction of the immensity of geological time, moves with an ease and freedom from cause to effect wholly denied to those wanting in this conviction. No doctrine in Geology has resulted in such brilliance of discovery as the doctrine of uniformitarianism, which sets no theoretical bounds either to the efficacy of present causes or to the duration of past time. It is not, however, the eternity of geological time that this doctrine demands, but the assumption of the vast duration of the geological periods of which it has been made up. And if to this assumption the geologist adds the conscientious accuracy of the geodesist and astronomer, and not only takes for possible, but absolutely demonstrates by discovery after discovery the true extent of the æons that have gone to the making of the geological formations, he is certain to foster and eventually to establish in the minds of men a full and adequate conception of the immensity of geological time.

Geology in Particular.—I have said that the widest definition of Geology is that it is that science which, leaving to Astronomy the study of the heavenly bodies as a society, devotes itself to the study

of the earth as an individual; in other words, that it is a 'Geonomy' as contrasted with an 'Astronomy.' But while this description is justifiable in principle, it is open to the natural objection that it shares this earth-knowledge with many other sciences, especially with the science of Geography. Perhaps the shortest definition that has been made of our science, and one equally acceptable to its students and to those who view it from the outside, is that Geology is the 'science of the structure of the earth.' It is in and around that earth-structure that all geological ideas centre. In working out the solutions of the problems presented by that structure, Geology not only finds her own special and peculiar mission, but extends a hand to all her sister-sciences.

In studying the solid elements of that structure, Geology shades through the science of Mineralogy into that of Chemistry. In the study of the changes which the parts of that structure have undergone and are now undergoing it shades through the science of Meteorology into that of Physics. In the study of the successive surfaces of that structure it grades into the science of Geography. In the study of the stony relics of the vanished beings that once dwelt upon those surfaces it joins hands with the sciences of Zoology and Botany. In studying the phenomena presented by the sequence and inter-relations of the rock-formations which go to the building up of that structure, it finds the means of reading the past history of the earth and its living inhabitants—a glory reserved for Geology alone.

It was not until geologists discovered that the solid earth-crust had a structure which was made up of definite parts or 'formations' capable of individual recognition and description, each showing a special distribution in space and in time, and each marked by characteristic features capable of being compared, contrasted, and reasoned about, that the science of Geology attained individuality and became worthy of its name. It was this discovery—inaugurated by Lehmann and Guettard about the middle of the 18th century, made famous by Werner and his contemporaries towards its close, and established beyond all dispute by William Smith at the dawn of the next—that gave Geology a claim to be regarded as one of the concrete sciences, and placed in her hands the weapons with which she has fought her way onwards irresistibly to the conquest of her kingdom.

Since the days of William Smith, the careful investigation and mapping out of these geological formations, igneous as well as aqueous, has spread outward from the original centres of investi-

gation with extraordinary rapidity, until at the present day there is hardly a civilized nation that does not possess a Government Geological Survey. The fascinating problems presented by these formations and the light which their solution has thrown upon all that concerns the past development of the earth and of its living inhabitants, have not only attracted hosts of enthusiastic students to the science itself, but have given it a far-reaching interest to countless workers in other branches of knowledge and opinion. As a consequence, there is hardly a single important intellectual centre in the Old World or the New which has not its own Geological Society, emulative of our own, whose members are either engaged in aiding the advance of that science or profiting by the benefits of that advance. One and all—national surveyors, members of Geological Societies, sympathizers in other sciences, collective bodies or isolated individuals—are united in a catholic freemasonry by their common study of, and interest in, the rocky structure of the earth.

I will not attempt the impossible by endeavouring to follow in detail the various stages in the development of geological science, or by trying to distinguish between what is due to the researches of its own students, and what is due to the aids afforded them by the fellow-sciences. But none among us would venture to deny the assertion that no branch of scientific inquiry has profited more than Geology from what has been termed the 'consensus of the sciences.' No science has received more ungrudging assistance from other sciences, or has repaid more fully that assistance in kind. Almost every problem attacked by Geology has needed the aid of some other branch of knowledge for its solution; almost every advance made by Geology has furthered the progress of one or more of its fellow-sciences.

Geology and Mineralogy.—The discovery of the geological formations themselves may be said to have been essentially the outcome of the early association of Geology and Mineralogy. The brilliant ideas of Werner, embodied in his so-called 'Geognosy,' in which these formations were first identified by their mineral characters, and then followed over their vast geographical extension until they were shown to stand related to the whole of terrestrial nature and of life, had unquestionably their root in Mineralogy; and the geological student of the igneous formations is incapable of his task unless he is well acquainted with the latest methods and results of mineralogical science. But the idea of the inevitable association

of Mineralogy and Geology must not be pressed too far, nor should it be allowed to give to the whole of Geology that dominant mineralogical colour in which it is often erroneously supposed to be steeped. It is impossible to over-estimate the advantages which have accrued to the science of Geology by its association with Mineralogy. But that association is an alliance and not a conquest. Geology is not a province of Mineralogy, but an empire in its own right, and between it and that of Chemistry, Mineralogy is, as it were, a kind of buffer-kingdom having alliances with both.

But if Geology owes much to its alliance with Mineralogy, Mineralogy has benefited by that alliance to quite as great an extent. Not only have all the minerals their home and habitat in the rock-formations, but the mineralogist owes to the geologist all that he knows of their association and distribution. In no branch of our science has Mineralogy aided us more than in that of Petrology, which has made such marvellous strides during the past generation; but that debt of obligation has been well repaid. To the petrologist is owing the discovery of the special association of the minerals in the igneous rocks, their relative order of generation, and their mutual interferences; and following upon this he has made known hosts of unexpected data rich in fascinating problems, opening out a new world of speculation and research both for the mineralogist and for the chemist.

Geology and Biology.—But if Geology owes the first suggestion of the geological formations and their individualization to Mineralogy, she has received benefits of as long standing and of as great a moment from Biology and biologists. The solid foundations of the palæontological side of Geology were laid by the Continental biologists ranging from Steno to Cuvier, simultaneously with the discovery and the working out of the order of the geological formations. Nothing in the history of the growth of Geology so astonished mankind, or so effectually aided in lifting and dispersing the dark cloud of obloquy and neglect which hid from the world the magnitude of the results attained by the early geologists, as the demonstration by the biologist that the extinct organic remains collected from the geological formations were identical in structure with creatures living upon the earth at the present day, and that all these fossil forms fell naturally into a place in the accepted biological classifications. At every successive stage in the progress of stratigraphy since that time, the geologist has been similarly indebted to

the biologist for the interpretation and classification of his fossils; and when we have respect to the rarity and to the fragmentary condition of many of these forms, we cannot sufficiently express our gratitude to Biology for the aid which she has afforded us.

But there is no need to claim that Geology has repaid the debt. It will be enough if I quote here two short receipts handed in on our behalf, one by the most distinguished biologist of the latter half of the century just closed, and another by the present occupant of his chair. In the words of Huxley, 'the doctrine of evolution in Biology is a necessary result of the logical application of the principles of the geological doctrine of uniformitarianism to the phenomena of life; Darwin is the natural successor of Hutton and Lyell, and the "Origin of Species" the logical sequence of the "Principles of Geology".' These words were written by him about twenty years since, and his successor, in reviewing from a morphological standpoint a few months ago the work of zoologists accomplished during these twenty years, speaks as follows:—'The progress through which we have passed has produced revolutionary results; our knowledge of facts has become materially enhanced, and our classifications have been to a large extent replaced in clearer and more comprehensive schemes; and we are enabled to-day to deduce with an accuracy proportionate to our increased knowledge of fact the nature of the interrelationships of the living beings, which with ourselves inhabit the earth. . . . Satisfactory as is the result, it must be clearly borne in mind that its realization could not have come about but for a knowledge of the animals of the past.'

It is at the present day the habit of some to hint that Palæontology, as geologists understand it, is a mere branch of Biology, just as it was the fashion half a century ago to look upon it as a branch of Geology. But the proper view, I take it, is to regard it as the common possession of both these sciences. Here, as in so many contests of opinion, the truth lies in the middle. It is undeniable that all the organic remains discovered by the geologist were in their day members of the great biological chain of life, and have therefore their individual places and relationships in the scheme of biological classification; and that as a consequence the study of their structure and their relationships falls within the province of Biology. But it is equally undeniable that each of these creatures had an existence during a definite range of geological time, and that its fossilized remains occur at a certain horizon in the

ascending series of the geological formations. They have thus a geological arrangement and grouping as inevitable and necessary as the biological one. While we grant that the biologist has not only a right but almost an obligation to place in its systematic biological position in his museum an example of every species hitherto discovered by the geologist, it is equally important for the advancement of science in general that the geologist shall have in his museum a stratigraphical grouping and chronological arrangement of fossil species always available for his geological work. There is a phylogenetic grouping by affinity for which the biologist is constantly striving, and to which he is daily more and more approximating; but there is also a chronological grouping by geological position, which for every individual specimen in the palæontological department of a geological museum was practically fixed the day when that specimen was collected from a known stratigraphical horizon. We may rest assured that, year by year, the stratigraphical classification in our geological museum will become more detailed and more refined. This chronological grouping constitutes a tool with which Geology cannot possibly dispense. Again and again, in the years gone by, the apparent sequence and the known palæontology have been in conflict as to the true stratigraphical position of local formations, and in every known case hitherto the palæontological side has scored the victory.

But indeed, if we Geologists were ever to become so benighted as to neglect this detailed sequential classification of the fossils in our museums, the biologists themselves would soon force it upon us for the sake of their own science. Fossils as thus arranged are and can be the only tangible proofs of the chronological order in which the various types and forms of life made their successive appearance on the earth; and they are in consequence the clearest and most widely accepted evidences of the doctrine of biological evolution. And further, the more minutely they are arranged in stratigraphical detail, and the greater the number of species, varieties, or mutations which are arranged under each horizon, the sooner will biologists have at their command the necessary materials enabling them to solve those great outstanding problems that bear upon the laws which have ruled in the origin, variation, and distribution of species.

Geology and Geography.—Turning next to the relations between Geography and Geology, we may say, perhaps, that there are no two

sciences more intimately connected, or more mutually beneficial. I have already referred to the natural claim of some geologists that logically Geology includes all that is contained in the study of the earth. But it might better, perhaps, be said that Geology and Geography share much of this collective study between them. Geology deals with the past of the globe and Geography with its present,—the former having, so to speak, the charge of its history, and the latter of its politics. The surface of the globe is their common limit, and, in a way, their common property. All that comes above that surface lies within the province of Geography; all that comes below that surface lies inside the realm of Geology. The surface of the earth is that which, so to speak, divides them and at the same time 'binds them together in indissoluble union.' We may, perhaps, put the case metaphorically. The relationships of the two are rather like that of man and wife. Geography, like a prudent woman, has followed the sage advice of Shakespeare and taken unto her 'an elder than herself'; but she does not trespass on the domain of her consort, nor could she possibly maintain the respect of her children were she to flaunt before the world the assertion that she is 'a woman with a past.'

It is almost superfluous even to hint at the aid afforded by Physical Geography to Physical Geology, or to attempt to show how mutually dependent the two have always been one upon the other. At first Geology was looked upon merely as a branch of Physical Geography; De Saussure, who first gave the name of Geology to our science, was himself in the front rank of the physical geographers of his day. The study of the whole array of terrestrial phenomena described by the physical geographer is, if anything, even more necessary to the educational outfit of the young geologist than the study of Mineralogy and Chemistry. Without the aid afforded by the study of the present phenomena which properly fall within the ken of the physical geographer, 'the conquests of Hutton and Lyell would never have been achieved, and the true philosophy of Geology would have been impossible.'

Again, every advance made by the geographical surveyor in the accuracy and details of his maps has resulted in a corresponding improvement in geological mapping and surveying. Every advance made by the descriptive geographer in the discovery, delineation, and description of the geographical relief of continental lands, or of the depths and deposits of the sea, has increased geological knowledge, and has stimulated geological enquiry and discovery in an almost corresponding ratio.

But, in this case of Geography and Geology as in others, the benefits have certainly been mutual. Broadly speaking, almost the whole of that vast mass of information which geographers now possess, respecting the work of those agencies which rule upon the dynamical side of Physical Geography, has been wrought out and accumulated by geologists engaged in searching for the causes of geological action in the past. The grand processes of denudation, erosion, and deposition ; the multifarious action of rain, rivers, and ice ; the phenomena of earthquakes and volcanoes ; and the rock-making activities of animals and plants, were most of them first laboriously investigated by geologists, who welded them into tools for work in their own science, and then handed them over bodily for permanent lodgment in the well-filled storehouse of the physical geographer.

As regards the surface of the earth itself, so numberless of late years have grown the visible and certain points of contact between the phenomena previously regarded as proper to the one or the other of the two sciences of Geology and Physical Geography, and so evident to all has become the sequence of geological causes and geographical effects, that many geographers have of late years almost lost consciousness even of the existence of a possible downward limit to their science. Revelling in the wealth of geological facts and ideas already accumulated and lying ready to their hand, scientific writers have combined with their geographical description of the 'forms' of the surface of the earth the geological explanation of their origins in that most interesting branch of knowledge which is sometimes named 'Geomorphology.' This is undoubtedly a section of geonomic science, which is of great value, and is destined to grow in importance as time goes on. But its study presupposes a preliminary education in which Geology and geological causes take perhaps the largest share ; and those who would class it merely as a sub-science of Geography are as wrong as those who class it merely as a sub-science of Geology. It is the healthy and vigorous child of both.

Geology and Physics.—Here we enter upon more difficult and dubious ground, namely, the relations of Geology to the science of Physics, especially in the matter of the so-called 'hypogene' agencies. The mechanical modes and means of formation of our mineralogical rock-sheets have long since been recognized and agreed upon, but the mechanical modes and means of their deformation have, many of them, yet to be identified and established. In the

matters of cleavage, jointing, and foliation we have advanced, and in the modes and effects of faulting we have already made some headway. But in the grander problems of orogeny, crust-warping, and secular elevation and depression, we are still very much in the dark. In spite of all the brilliant work which has been done of recent years, we are forced to acknowledge that we are still busied in collecting data upon which to found a philosophic system of crust-deformation. Nothing yet formulated in this direction is of sufficient definiteness and breadth of grasp to afford matter from which anything more than suggestive deductions may be drawn by the higher physics and mathematics.

But although our materials are as yet too heterogeneous and too complicated to admit satisfactorily of such outside analysis, yet among geologists themselves there is being developed a tendency to assort and interpret them from two extreme points of view, which may perhaps be distinguished as the astronomical and the geonomical.

The working theory employed by the many at the one extreme is the collapse-theory, which is founded essentially upon the (contraction) hypothesis of the gradual loss of heat of the earth's interior. This theory starts from the original covering of our globe, and regards the present state of that covering as that of a solid and more or less cooled crust, which warps, folds, and fractures as it follows down upon the slowly contracting, but still intensely heated (and probably solid) nucleus. This crust shows in its structure and in the major forms of the outer surface the combined effects of the radial and tangential deformations due to the contraction and collapse, these deformations being grouped about the remains of the chief irregularities proper to the crust at the time of its original consolidation.

The working theory employed by the few at the other extreme is the fold-theory, founded essentially on the (undulation) hypothesis that the deformation may be largely due to tidal movements and to the constant redistribution of load and resistances. It starts from the known modes of deformation of the rock-sheets which make up the present supercrust and of those of its superposed coverings of water and of air. It regards the earth-crust as a spheroidal shell or bridge surrounding and balanced upon a fluid nucleus (probably gas-like), the shell being in a state of general vibration and its parts in a state of regional and local stress. This shell yields harmonically as a whole; and its various parts yield in groups or individually to

the several stresses, but always in theoretic units (duads) each made up of two moieties which are the positive and negative equivalents of each other.

According to both theories, the type of deformation may be that of undulation, warping, folding, gliding, fracture, or flow, according as the magnitude of the stress, the speed of the action, or the relative elasticity of the material may determine: its development may range in time from that of an instant to that of an æon; and its extent from microscopic to hemispheric.

According to the first theory, however, the deformation is not theoretically symmetrical, but is consequent upon and has ever been controlled by the salient features of the original earth-crust. According to the second, the deformation is theoretically symmetrical, and is due to the continual breaking-down and readjustment of equilibrium; it is at every stage controlled by the length and direction of the instantaneous polar and equatorial diameters of the earth, and by the summational and individual deformations already effected.

The tendencies of the first theory are to compare all the phenomena of yieldage with those characteristic of solid bodies, and to dwell especially upon the proofs of fracture (with the fault as the central type); to parallel such signs of symmetry as are apparent with that of crystals, and the loxodromic trend-lines of the earth's surface with those of crystalline cleavage. The tendencies of the second theory are to compare the yieldage-phenomena with those of flexible bodies (with the fold as the central type), grading on the one hand into those of rigid, and on the other into those of liquid bodies, and including all types; to parallel the symmetries with those of wave-forms, and to refer the trends to composition, interference, or superposition as the case may be.

In the first theory there is inherent the expectation of continuous accretion and discontinuous collapse; in the second the expectation of rhythmic recurrence of form in space and of movement in time. According to the first theory the locus of the pole of the land-hemisphere on or about the 45th parallel is an accident of evolution and a survival; according to the second it is a theoretic necessity and a resultant.

How much of each of these views is a mere mental expedient, and how much is an expression of fact, must be left for future research to determine. The discovery of the true path lying between the two extremes will form one of the tasks which await the geologists of the coming era.

Geology and Practice.

Geology and the Useful Arts.—Up to this point I have dealt mainly with the so-called 'scientific' aspect of Geology, regarding it from the inside point of view,—as an interpreter of Nature, and a member of the great family of the sciences. But, as I have already hinted, we are bound also to consider it from the outside or 'practical' point of view,—as being one of the servants of mankind and an associate of the useful arts. Indeed it is wholly impossible to avoid dealing with it from this outside aspect. In the words of Herbert Spencer:—'Not only are the sciences involved with each other, but they are all inextricably interwoven with the complex web of the arts, and are only conventionally independent of it. Originally the two were one, and there has been a perpetual inosculation of the two ever since. Science has been supplying art with higher generalizations and more completely qualitative previsions; art has been supplying science with better materials and more perfect instruments. . . . And all along this interdependence has been growing closer, not only between the arts and science, but among the arts themselves and among the sciences themselves.'

I have already noted how greatly Geology is indebted to her sister-sciences, and how in every case the aid which she has been given has been fully reciprocated and the mutual sympathy broadened and enlarged. Surely there is no need for me to recall how deep and how fundamental are the obligations which Geology owes to the arts in general, and to those of mining, engineering, and topographic surveying in particular. But it may not be without advantage if we geologists remind ourselves of that which in the absorption of our researches we are sadly prone to forget, namely, the existence of those many links that bind our science to the world of practice, and the vital need there is of strengthening those links by every means in our power.

It is true that the first duty of every science is to move incessantly forward from discovery to discovery along the straight path of unremitting investigation and research, following truth whithersoever it may lead, wholly unbiassed by the question as to whether that discovery bears any relation whatever to the material wants of mankind. But it is equally true that once a fresh fact has been discovered, or once a new and satisfactory conclusion has

been reached, if that fact or that conclusion be of evident benefit to mankind at large, every lover of his science should welcome its utility and do his best to encourage its use.

Here, however, we cannot ignore the fact that it is impossible that full use can be made of the results of any science until those to whom such results would be of practical value are educated at least in the principles of that science. And such education has a double value; it is not only of especial advantage to those who intend to make use of the results of the science, but it redounds to the benefit of the science itself, for it trains up a host of sympathetic students all concerned in its advancement.

We cannot fail to recognize that those sciences—such as Chemistry, Physics, Biology, and the like—which are generally acknowledged to be most intimately bound up with practice, and an education in which is held to be absolutely necessary for success in one or more of the arts or professions, are the sciences which have the greatest number of students and are making the swiftest progress. It is the height of absurdity to imagine that Geology can, any more than any other science, possibly restrict its activity to research alone. Rather may we say that the corporate geological organism has three necessary functions—research, practice, and education. So long as all three functions are naturally and healthfully performed, so long will Geology live and flourish. Whenever either function remains long unexercised, or falls into disuse, there follows, of necessity, a weakness throughout the entire organism, which must in the end become lethargic and crippled, and fall behind in the race.

When, on the other hand, all three functions are most vigorously exercised, the progress of the science must be at its swiftest and its surest. And this fact has been well illustrated in the history of our science; for whenever these three functions of Geology have been most clearly appreciated and simultaneously energized by its leaders, Geology has shone forth with an especial and peculiar lustre, and has won the attention and regard of the world.

Those who came from all parts of Europe to attend the lectures of Werner, were drawn to him by his conviction that Geology was one of the most useful of trainings not only for the men of the mining and metallurgical world, but also for those who were interested in all that concerns Man's relation to the earth in general. They listened with delight and with profit to the brilliant exposition of his far-reaching ideas, not only because they felt the

fascination of these ideas, but also because they were impressed by his assurance of their material and intellectual utility. The geological education which they received from him, they communicated in their turn to their own pupils, and rapidly spread the benefits and influence of Geology far and wide over the economic and intellectual world of their time.

But we have even a more striking instance nearer home. I do not think that it is too much to assert that no single geologist, whose name adorns the long roll of the past members of this Society, secured at one and the same time so far-reaching an influence upon the spread of geological knowledge at large, so sincere a respect for our science from the Governments of civilized countries, and so kindly a regard and affection for it from the mass of mankind, as Sir Henry De la Beche. And I take it that all this was due to the fact that he, more than any other British geologist before him or after him, had a clear and well-balanced conception of the three functions of geology. He was at once a scientist, a practical man, and an educationalist.

No one familiar with his 'Geology of Devon & Cornwall,' or with his 'Geological Observer,' but will grant that he was, both from the side of research and theory, a scientist to the backbone. But he was more than a scientist. He was a man whose life-work had convinced him that the useful side of Geology is as important as the intellectual, and indeed of the necessity there is for the constant union of science and practice, or, as he puts it himself, 'Science and practice are not antagonistic, they are mutual aids.' And mainly, perhaps, because of this conviction, he was also a keen educationalist; for, as he himself expresses it, as 'some reason, right or wrong, is sure to be assigned to every practice, it is most important for those connected with that practice that they should possess the existing knowledge upon which it rests.'

De la Beche devoted some of the best years of his life to the task of convincing the Government and the people of this country of the importance of the knowledge of the science and practice of Geology and its related sciences to the material and intellectual advancement of the nation. He brought round the Government of the day to his views, and the best minds of his time, from the Prince Consort downward, became his enthusiastic supporters. He created the British National Geological Survey, which has proved itself as beneficial to the advance of pure Geology as it has to the development of the mineral resources of the Kingdom; while it has

been the prolific parent of similar national Geological Surveys in almost all countries of the civilized world. He founded the Museum of Practical Geology as a national home for the collections made by geological research and for the illustrations of Geology in all its practical applications, consecrating the building, even in its title, to that idea of the combination of knowledge and utility which justified the nation in its foundation and its maintenance. And more, he made that Museum, through his genius and his knowledge of men, a living and growing centre of instruction in geological science and its useful applications, selecting as the teachers of that special education some of the highest intellects of his day.

What other scientific leader of the 19th century can show so famous a roll of lieutenants? It is almost invidious to select names from the list. But so long as Natural Science, pure or applied, shall command the respect of men, the names of Thomas Huxley, Lyon Playfair, Edward Frankland, John Percy, Edward Forbes, and Andrew Ramsay, will be held in honoured memory as those of men whose lifework in science, or in practice, or in education, or in all three combined, place them in the front rank of the benefactors of their day and their generation.

We might go on to point out how the success of De la Beche's scheme caused it to outgrow rapidly the limits of its original home, for we are most of us familiar with the fact that while the Geological Survey and the National geological collections are still retained in the original Museum, the educational sections became developed into the Royal School of Mines and eventually into the Royal College of Science, which in its turn practically became the centre of that widespread scheme of national instruction, known as the Science & Art Department. But what especially concerns us here, is that these results demonstrate, on the one hand, the naturalness and fertility of De la Beche's conception of the necessary association of science, practice, and education, and on the other the far-reaching influence that Geology and geologists have had on the extension and invigoration of scientific practice and education in Britain.

Geology and Economics.—It is almost an impertinence to point out to an assemblage of geologists like this the relationships of Geology and its applications to the material welfare of our fellow-countrymen; but those of us who are absorbed in the charms of research are now and again tempted to look askance at those who are engaged in advancing Geology and the

applications of Geology from the side of Economics. Yet for all that, every one of us is well aware that Geology is bound up body and soul with the development of the mineral wealth of our land—that mineral wealth by means of which the enterprise of our people has placed our country at the head of the manufacturing and commercial powers of the world. Our science has not only the charge of the working out of all the detailed phenomena, subterranean and superficial, of the great coalfields and iron-ore fields which lie at the foundation of our commercial supremacy as a nation, but it works out the characters and fixes the places of all the stony materials of which our cities and towns are built, our humblest dwellings are constructed, and all our roads and railways are made. It deals with the sources and the quantities and characters of our water-supplies, whether deep-seated or superficial, the nature and distribution of our soils, and indeed with everything which we derive directly from the ground upon which we tread. Thus a knowledge of the principles and applications of Geology is indispensable to the education of the miner, the mine-owner, the prospector, the land-agent, the landowner, the agriculturalist, the civil engineer, and the military engineer.

Geology and Man.—It is as true now, as it was in the days when Werner first drew his far-reaching inferences before his charmed listeners, that in the characteristic phenomena and varying distribution of the grand mineral masses of the rock-formations, almost all that concerns the relative habitability of a land depends. Where the hard, intractable rock-formations rise boldly out, we have our mountain-regions — our Uplands and Highlands — wild areas of pasture and scanty populations it is true, but the lands of refuge and of freedom in the past, and of health and holiday in the present. Where the soft, easily-weathered rock-formations spread out in gentle slopes or broad undulations, we have the wide plains of our great agricultural districts—the lands it may be of peace and plenty, but where life is so easy-going and so monotonous that there is little incentive or opportunity to vary the established order of things, and the local country-life remains much the same generation after generation. Between these two extremes lie the areas floored by the gently-inclined rocks of our great coalfields, the theatres of an incessant and fierce industrial struggle—a struggle that has its reflection and its effects in the restless energy and the determined advance of their inhabitants.

What well-read geologist among us is not aware that every variation in the contour of our country, as it rises from the encircling seas that have guarded our freedom, is dependent upon its geology? Where the hard rock-formations reach the seaboard, project the bold headland and its cliffs. Where the soft rocks come down to the shore-line, open out the broad bays. Where the highly resistant rocks are lifted up in broad mass and face the wild ocean, we find a shore-land of rugged cliffs and wild inlets, inhabited only by a few hardy fishermen. Where the easily-yielding rocks have been depressed in mass by geological movements, we have the long-withdrawing estuary, alive with the ships of commerce moving to and fro from the busy and populous seaport at its head.

Or turning inland and looking over the general aspect of the country, we recognize everywhere not only the paramount influence of the geological formations and geological conditions on the scenery and the relief of the land; but we trace everywhere the persistent effects of these conditions upon the past and present of the people. All the activities of struggling humanity, in the contest for the bare necessities of existence, for mutual protection, for trade and for progress, have been limited and controlled by the natural bounds marked out by the unvarying geological factors. The original sites of almost every city and town, village and hamlet, ancient castle and modern mansion, were all determined practically by geological considerations. The sites of the old fortresses were fixed by the places of the more or less inaccessible cliffs and scarps, the position of the villages and hamlets by the abundance of the springs, and the settlement of the lands by the comparative richness of the soils. All down the long stream of history, the successive waves of invasion, the ebb and flow of conquering armies, the tracks of inland trade and communication, from the time of the Roman ways, through the roads of the Middle Ages and later, down to the main threads of the network of railways of the present day, have all more or less followed the same general courses, courses determined by the geographical phenomena consequent upon the geological structure of the land.

It is idle to pursue these matters further, or recall how all the variations in scenery and scenic beauty are dependent upon geological causes; or how these causes determine the productiveness or the healthfulness of a district. But it is impossible for us, to whom these matters are as familiar as household words, to conceive that the education of the geographer, the traveller, the man of commerce,

the student of hygiene, the artist, the archæologist, the historian, or even the politician can possibly pretend to completeness unless that education has shown him something of the wealth of facts and ideas that flow even from an elementary acquaintance with a knowledge of these things.

Here perhaps we may call to mind the fact that what gives character and especial colour to the science of Geology, is that it is the exponent of the idea of continuous evolution. I had almost said the discoverer; for 'he discovers who proves.' Its widest conclusions are based upon the assumption and proof of the efficacy of small causes to bring about the greatest cumulative effects. There is probably no educational gymnastic more captivating and invigorating than to work out and fully appreciate the quietly cumulative effects of present natural causes—the sea-waves gnawing away the shore, the slow sinking of mud layer by layer on the sea-floor, the quiet burying-up of organisms; next to trace these phenomena backward stage by stage through the rock-formations that mark the æons of the past, down to the very base of the geological scale; and, thence returning, to climb back step by step up the long ladder of life, and note the successive incoming of the ascending types of the animate creation, rising higher and higher yet in the scale of being to the crown of all—Man himself—'the heir of all the ages.'

The discoveries which Geology, in company with Archæology and Anthropology, has made in aid of the solution of the great problem of the Antiquity of Man, are so revolutionary and so recent that they are practically familiar to all.

To one who has gone through a geological training, and appreciated its meaning, the idea of slow and continuous evolution becomes as it were part and parcel of his mental constitution. He naturally carries on the same geological methods into the study of humanity in general—always from the developmental point of view, always on the watch for those simple natural causes that may have been capable of bringing about the present known effects, and always in the hope of discovering a slow and natural evolution. It is in this way that he studies the races of mankind, the growth and relations of languages, the forms and distributions of beliefs, the trends of political practice and opinion, the origin and expansion of commerce. He is watching, and indeed as it were assisting in, the development of a living thing growing up before his mental eyes. His interest is excited, his curiosity piqued, and his emotions stirred; and while his imagination is allowed full play, it is always

safely confined within the logical bounds of induction, deduction, and verification.

Surely some kind of knowledge and training of this kind is much to be desired for the ordinary man of education and leisure, the literary man, the arts man, the mathematician. Only by some means of this kind does it seem possible to restore the loss of balance due to the self-absorptive and introspective tendency of much of the so-called culture of the present day. Only by some means of this kind can one attain to the needed breadth of outlook and freedom of opinion as respects all that concerns the relation of man and nature.

Geology and Education.

We have seen that a knowledge of Geology is indispensable to the complete education of the miner, the prospector, the civil engineer, and the military engineer; and that a first-hand acquaintance with at least its elements is eminently desirable for the agriculturist, the geographer, the traveller, and the biologist. Many may even be willing to admit that the literary man and the man of culture would be the better for knowing something of its principles and its conclusions. But, as geologists, it is our bounden duty to go much farther than this, and urge upon the educationalists of the day the necessity of affording the rising generation such a full opportunity of instruction in that kind of knowledge of which Geology is the keystone as shall enable our youth to understand and appreciate the more important phenomena of the world at large, and the bearing of these upon their own life and surroundings.

Nothing, however, is further from my intention than to suggest that all the youth of the country shall be instructed in the science of Geology as such, or that Geology shall be introduced as a special subject of education, except into the higher classes of schools, colleges, and universities. But what I have in my mind is that Geology is the centre of that group of knowledges which are sometimes collectively referred to as 'Nature-Knowledge,' and their study as 'Nature-Study.' The more advanced educationalists have long since suggested and even strongly advocated instruction in Nature-Study for all our youth; but, alas, they are not yet agreed as to what 'Nature-Study' shall include, or how it shall be taught. At the one extreme are those who apparently would embrace within it instruction in and explanation of all such concrete facts and

phenomena as can be brought before the notice of the youthful pupil so as to direct his attention to external nature in general. At the other extreme are those to whom this dwelling upon facts and phenomena appears to be repugnant, if we may judge from the following extract which I take from a recently-published book-catalogue:—'To those who are striving to make Nature Study more vital and attractive by revealing a vast realm of Nature outside the realm of science, and a world of ideas above and beyond the world of facts, the pages following, giving the titles of books dealing with Nature and Nature-Studies, are dedicated.' As geologists, however, we should presume, I take it, that education in Nature-Study is, in the words of Huxley, 'education in that diligent, patient, loving study of all the aspects of Nature, the results of which constitute exact knowledge, or Science.'

Education in Earth-Knowledge.—However that may be, this at all events is clear: the branch of Nature-Knowledge with which Geology and geologists have to do is that which Huxley terms 'Erdkunde, or Earth-Knowledge, or Geology in its etymological sense.' So impressed was Huxley with the general need for instruction in this kind of Earth-Knowledge, that he practically founded for its study the educational subject which he named Physiography. Yet Physiography has come to embrace much that truly belongs to Astronomy; and, indeed, a very large proportion of the subject of Physiography, as taught in many schools and colleges in Britain at the present day, is essentially astronomical. But here we have to bear in mind that of the two great divisions of Nature, that of the outside universe which is proper to Astronomy concerns individual men but indirectly. The other half of Nature, if we may call it so—the world upon which we live and amidst whose phenomena we move and have our being,—is always with us and around us; and its conscious systematic study, which we call 'earth-knowledge,' is in truth only a methodizing and an extension of the unconscious and unsystematic study that we call 'experience,' which we are always making from the earliest dawn of our consciousness to the final darkness of old age. This is the kind of Nature-Knowledge—namely, Earth-Knowledge proper, or in other words 'Geonomy' as contrasted with 'Astronomy'—of which our youth has the greatest need; and it is instruction in this which it is one of the missions of Geology to claim for the rising generation.

The day has not yet arrived when it will be possible to define

precisely what should be taught under the head of this Earth-Knowledge. But what I would understand by it is that it should embrace instruction which would direct the attention of the scholar not only to the natural phenomena of the world at large, but also to those particular phenomena of the world immediately around him. In its general interpretation, its central plane would be the surface of the earth; and from this it would pass upward by proper stages to consider the distribution of all the phenomena, organic and inorganic, above that surface; outward to the study of the meaning and interaction of these phenomena; downward to the study of their history; and onward to the study of their evolution.

The teaching of this Earth-Knowledge could begin in the elementary classes of schools, be continued in rising grades through the higher classes, and thence extended to the universities. Speaking theoretically, in its earliest stages it should be as simple as possible and cover the ground which is familiar to daily experience or which is fundamental to several of the natural sciences. In its higher stages it should become more specialized, and include the facts and principles common to the special group of sciences which will become of value to the scholar in his later studies or in his after-life. In the university it might finally be restricted to the perfect knowledge of that one science which the scholar has selected for his speciality, and as much of the fellow-sciences as has an intimate bearing upon the science which he selects as his own. At every stage a broad foundation should be laid for the superstructure to be erected in the next stage of advance.

But, speaking practically, it is impossible at the present day to lay down any general rules as to the order in which the subjects dealt with under the head of Geonomy should be taken up, or as to the way in which those subjects should be individually treated. For while it is quite true that the aim should be to instruct in those generalities which are common to many or all of the sciences, we should most strictly guard ourselves from falling into the error implied by many of the text-book writers on Physiography, who start with an opening chapter on matter, energy, gravity, and the like—generalities in their essence as yet hardly capable of conception even by the highest intellects. And while it is quite true that the most vivid and lasting means of education is by experiments and deductions carried out by the pupil himself, we should as carefully avoid the equally fatal error of imagining that instruction

in a single experimental science, such as Chemistry and Physics, can do more for the pupil than give him a glimpse of a corner of nature.

It is sometimes suggested that instruction in Earth-Knowledge should commence with the simplest facts and deductions, and lead up stage by stage to the highest philosophical conceptions and generalizations. But this is not the way in which any branch of knowledge has grown and developed in the past. The human mind is so constituted that it can often appreciate the broadest generalizations in some directions, before it can interest itself in the most elementary facts and draw the simplest conclusions in others. What must be done is to ascertain, from the study of the several branches of knowledge, how they have individually grown during their developmental history in past ages, note the order of subjects which were earliest and most easily appreciated by the human intellect, and give the successive phases of education as nearly as may be in that order.

Again, it is sometimes hinted that the only fruitful education is that which is purely experimental, the deductions and generalizations in which shall be worked out by the scholar himself; and also that all knowledge which is imparted by the didactic method is not true knowledge and is comparatively infertile. But I firmly hold that both methods are correct, each for itself, and should both be utilized. There are unquestionably some things which are best taught by experiment, and by that demonstration in which the pupil takes the whole or the largest share. But, on the other hand, the facts of science are so overwhelming in number, and some of its grandest conclusions are so dependent on the highest extremes of knowledge, that they must be communicated didactically, and must be accepted by the scholar more or less as an article of faith. Indeed the younger the scholar, and the less his experience, the more certain is he to accept as unquestionable truths the assertions of his instructors. It would be the height of folly to neglect the advantages of all this side of a youth's education in those years of his life when he is most qualified to profit by it.

The fact is that in the imparting of Earth-Knowledge, as in any other kind of instruction, both educational methods—didactic and experimental, authoritative and original—should be utilized together. It is a matter for the educationalist to find out what sections of a subject, and what stages of a subject, are best imparted by one method and what by another. The only rule

which can be laid down is that the didactic and authoritative method is certain to have less and less effect as the scholar grows older and his experience broadens, and the experimental and original more and more. But there is no escape from the conclusion that it is the common interest of the teacher and the scholar to make use of both methods; for the knowledge of every man—the genius, the scholar, the wise man, and the fool—is alike in this, that it is the sum of that knowledge which is due to his own individual experience, and that portion of the collective knowledge of humanity which is due to the antecedent experiences of his forefathers, and which he has received at second-hand. It is not that the present educational systems are wrong in laying stress on the memorizing and the applying of what is already known, but that they are defective in neglecting the individual and original half of a liberal education.

As I have already pointed out, the central plane of Geonomy is the knowledge of the surface of the earth, whose present and whose present conditions belong to Geography, and whose past and evolution belong to Geology. But in the earlier phases of the education of the scholar there can and need be no distinction in his mind between these two sciences ; they are rather combined in a geonomic stage—in a generalized organism, so to speak,—destined to evolve and differentiate later on. Yet in this early stage the dominating section of the subject is essentially Geography. As such it presents two very different aspects : the general geography, namely, that of the world and its surface as a whole ; and the local geography, namely, the geography of the home and the surroundings of the scholar. The general geography must be taught didactically, with the aid of such lecture-illustrations as globes and maps ; and the instruction must be received by the scholar more or less as an article of faith. The local geography, however—and by this I would understand not only the topography of the district, but the geography of the town or village, the playground, and the very schoolroom itself,—should be taught practically at first hand, the data being recognized, collected, and classified, the experiments made, and the conclusions drawn, as much as possible by the scholar himself.

Maps as Means and Symbols of Earth-Knowledge.—It is along this local side of Geonomy that some of the most important advantages will accrue to Geology, and not only to Geology but to all its associated sciences. One of the most necessary qualifi-

cations for the geologist and the geographer, and indeed for all students of those sciences and arts in which facts and phenomena have to be arranged in their order of distribution, is a familiarity with the use of maps and a knowledge of how they are constructed. But one of the commonest results of the present modes of giving instruction in maps and map-making in most schools is to cause this kind of knowledge to become distasteful to the learner. And the consequence is that for one fairly well-educated man who can read a good map of his own native district, there are hundreds to whom this is impossible. A detailed topographical map or a geological map is practically a mystery to the average man; and yet the training which would have enabled him to appreciate and enjoy them both might, if given properly in his early years, have afforded him many a pleasant and interesting break in the monotony of his ordinary school-work. He has doubtless been shown in his geographical classes the ordinary maps of the world, and those of the continents and his own country; he has perhaps copied some of them laboriously in manuscript, and very probably passed examinations in drawing them from memory. But they were always more or less dead things to him, because they dealt with lands and districts which he had never beheld, and not with the familiar objects of the school and the home. He has never seen them grow up before his own eyes, built up from facts collected by himself and his fellows.

We should like to see the lower classes of all schools making a map of their own schoolroom and playground. We should like to see the scholars at a higher stage studying and exercised in the large scale 25-inch map of the locality, with the school in the centre; those at a higher stage engaged on the 6-inch map of the neighbourhood; and so on. Stage by stage the scholars might pass to the study of the 1-inch map of the district or county. Then, when once these maps had become familiar objects, the learners should be taken out on occasional excursions into the country with the maps in their hands, and educated in some of the higher grades of that Earth-Knowledge which can only be seen and appreciated in the open air. Later on the scholars might pass to the study of natural agencies, the origin and meaning of landscape, to geology proper, and thence to the study of the intimate relations of nature and man.

But it must be acknowledged that the present lack of this kind of instruction is not to be wholly ascribed to the teachers. Good

local maps were, until recently, practically non-existent. The Government Ordnance and Geological Surveys have now made these at great national expense, but so hidden away are they that few except military and civil engineers and surveyors use them freely, and very few have recognized their perfection and importance. Now that these maps are becoming completed, we are beginning to discover that they constitute a most important educational engine. They are still, however, sold at too high a price. When we bear in mind the important fact that each member of a class should be provided with a fresh map at every successive stage, the cost to parents and school-managers of this branch of geonomic training, as matters stand, would be considerable. Yet we may be sure that this kind of instruction is certain to come about. It becomes, therefore, a serious question whether the Government departments concerned with the surveying of our country could not be authorized to supply these maps to school classes, either as part of the local Government grant or at a very cheap rate. The actual surveying of the country and the preparation of the maps already costs several thousands of pounds annually, which are ungrudgingly paid by the nation. Surely an extra yearly grant of a few scores of pounds to enable the Government map-making departments to supply these maps to schools at a nominal price, would be so trivial, whether compared on the one hand with the large grant already made for the original production of these maps, or on the other hand with their educational value to the rising generation, that it would undoubtedly be welcomed by all.

And once our people became aware of the excellence of these national maps, topographical and geological, the demand for them, which is comparatively small at present, would certainly grow. As yet, however, the public are hardly aware even of their existence. A great advance has been made of late by hanging up selected, but unfortunately not local, portions of these maps in post-offices, with a notice that the maps can be obtained from the local agent. But what are really wanted in all post-offices are framed copies of the 1-inch and 6-inch maps of the locality, hung up so as to be available for reference by all comers; and a copy of each of these and the other local maps kept in stock, together with a simple catalogue of all the national maps and memoirs, any one of which should be obtainable by return of post. The post-offices are, in the very nature of things, the best advertising places in the country; and they are in direct touch with the map-issuing departments of the Government.

Once the people become accustomed by means of their school-teaching, and by constant sight of these maps in the post-offices, to regard them as a factor in their daily life, that which is now a luxury for the learned and the few will become more or less a necessity for the general and the many; and they will demand, for themselves and their children, a more intimate acquaintance with that Earth Knowledge of which these maps are a symbol—a consummation in which the science of Geology will benefit by no means last and by no means least.

Conclusion.—But to what extent instruction in that earth-knowledge of which Geology is the soul and centre will constitute an integral portion of the general education during the present century must depend in part on the efforts of geologists, and in part on the enlightenment and emancipation of the educationalists themselves. As geologists, however, we have the assurance, justified by unbroken tradition, that our views will eventually be accepted simply because they are inevitable.

In the direction of practice also we may look forward with equal confidence, especially to the spread of geological facts and principles and to the extension of the applications of our science. The enormous increase in the utilization of the mineral resources of our country which is now going on, and the rapid opening up of the many mineral districts throughout the worldwide possessions of the Empire, bring day by day a larger array of students to our science from the side of economics.

And turning to the side of research, we are all of us aware that some of the grandest and most difficult problems of our science still await solution—problems as attractive, as stimulating, and as rich in promise as were any of those of the past. And if that past be a true index of the future, we may be well satisfied that there is no science which need outstrip ours in its rate of progress. When we call to mind that at the commencement of the great French Revolution, whose echoes have as yet hardly died away, our science was just struggling into existence, and that in the short time which has since elapsed it has placed itself abreast of the foremost, we have every incentive to push forward and to emulate those great pioneers in the science, in the mighty sum of whose conquests we rejoice and take a pardonable pride.

We have indeed abundant cause for pride, yet none for vain-glory. No science, it is true, has made so swift an advance as

Geology, but certainly to none has ever been afforded so magnificent an opportunity. The veil of ignorance and of traditional opinion which hid from the men of the Middle Ages the wonders which Geology has since revealed, was so dark and opaque that, until the close of the eighteenth century, no light could penetrate beyond. But so old and flimsy was it, that when once the strong hand of the geologist had torn it, it was soon rent through from top to bottom, and in the flood of light which entered, what wonder that discovery followed discovery in almost endless succession.

And we have deep cause for thankfulness in that these discoveries have been of benefit, not for our science alone, but for all its fellow-sciences; and more, that they have been from the first of supreme importance to man himself, his industries and his progress; and to the study of his history, his origin, and indeed of all that binds him and his fellow-creatures to the world on which he lives.

While, therefore, we move on confidently together in this dawn of a new era, blazing forward the straight and narrow trail of research marked out up to this point by our geological forefathers,—the 'old trail, the lone trail, the trail that's always new'—let us ever remember that our science is not only the interpreter of Nature, but also the servant of Humanity.

February 25th, 1903.

Prof. Charles Lapworth, LL.D., F.R.S., President, in the Chair.

Clements Frederick Vivian Jackson, Esq., Assoc.M.Inst.C.E., Assistant Government Geologist, Brisbane (Queensland); Ernest Lloyd Jones, M.D., Corpus Buildings, Cambridge; W. K. Spencer, Esq., B.A., University Museum, Oxford; and Harold Walker, Esq., Marley Brow, Bingley (Yorkshire), were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'On the Occurrence of *Dictyozamites* in England, with Remarks on European and Eastern Mesozoic Floras.' By Albert Charles Seward, Esq., M.A., F.R.S., F.L.S., F.G.S., Fellow of Emmanuel College, Cambridge.

2. 'The Amounts of Nitrogen and Organic Carbon in some Clays and Marls.' By Dr. N. H. J. Miller, F.C.S. (Communicated by Sir John Evans, K.C.B., D.C.L., F.R.S., For.Sec.G.S.)

The following specimens and photographs were exhibited:—

Specimens of *Dictyozamites* from the Inferior Oolite of Upleatham Hill, near Marske-by-the-Sea (Yorkshire), exhibited by A. C. Seward, Esq., M.A., F.R.S., F.L.S., F.G.S., in illustration of his paper.

Platinotype reproductions of Portraits of Distinguished Geologists in the possession of the Society, photographed by Messrs. Maull & Fox.

March 11th, 1903.

Prof. Charles Lapworth, LL.D., F.R.S., President, in the Chair.

The List of Donations to the Library was read.

The following communications were read:—

1. 'Petrological Notes on Rocks from Southern Abyssinia, collected by Dr. Reginald Kœttlitz.' By Catherine A. Raisin, D.Sc. (Communicated by Prof. T. G. Bonney, D.Sc., F.R.S., F.G.S.)

2. 'The Overthrust Torridonian Rocks of the Isle of Rum and the Associated Gneisses.'[1] By Alfred Harker, Esq., M.A., F.R.S., F.G.S.

[1] Communicated by permission of the Director of H.M. Geological Survey.

The following specimens and maps were exhibited:—

Rock-Specimens, and Microscope-Sections cut from them, collected by Dr. R. Kœttlitz in Southern Abyssinia, exhibited in illustration of the paper by Miss Catherine A. Raisin, D.Sc.

Rock-Specimens from the Isle of Rum, exhibited by Alfred Harker, Esq., M.A., F.R.S., F.G.S., in illustration of his paper.

Newly-issued colour-printed sheets of the Geological Survey 1-inch maps, England & Wales, n. s. No. 298, Salisbury (Drift), and Ireland, No. 112, Dublin (Drift), presented by the Director of H.M. Geological Survey.

March 25th, 1903.

Prof. Charles Lapworth, LL.D., F.R.S., President, in the Chair.

Adolphe Chalas, Esq., Lic. ès Sc., Nouméa (New Caledonia); and Russell Frost Gwinnell, Esq., Assoc.R.C.S., 33 St. Peter's Square, Ravenscourt Park, W., were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'On a New Species of *Solenopsis* [*Solenomorpha*] from the Pendleside Series of Hodder Place, Stonyhurst (Lancashire).' By Wheelton Hind, M.D., B.S., F.R.C.S., F.G.S.

2. 'Note on some *Dictyonema*-like Organisms from the Pendleside Series of Pendle Hill and Poolvash.' By Wheelton Hind, M.D., B.S., F.R.C.S., F.G.S.[1]

3. 'The Geology of the Tintagel and Davidstow District (Northern Cornwall).' By John Parkinson, Esq., F.G.S.

The following specimens and maps were exhibited:—

Specimens of *Solenomorpha* and some *Dictyonema*-like Organisms from the Pendleside Series, exhibited by Dr. Wheelton Hind, B.S., F.R.C.S., F.G.S., in illustration of his papers.

Rocks and Microscope-Sections, exhibited by John Parkinson, Esq., F.G.S., in illustration of his paper.

Eighteen sheets of Geological Maps issued by the Imperial Geological Survey of Japan, presented by the Director of that Survey.

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[1] This paper has been withdrawn, by permission of the Council of the Geological Society.

April 8th, 1903.

J. J. Harris Teall, Esq., M.A., F.R.S., Vice-President, in the Chair.

Wynne Edwin Baxter, Esq., J.P., D.L., 170 Church Street, Stoke Newington, N., and The Granvilles, Stroud (Gloucestershire); and W. E. Garnett Botfield, Esq., J.P., The Hut, Bishop's Castle (Shropshire), were elected Fellows of the Society.

The List of Donations to the Library was read.

Prof. W. W. Watts drew attention to the exhibit on the table of the new series of Platinotype Photographs about to be issued by the Geological Photographs Committee of the British Association.

The following communications were read:—

1. 'On the Probable Source of some of the Pebbles of the Triassic Pebble-Beds of South Devon and of the Midland Counties.' By Octavius Albert Shrubsole, Esq., F.G.S.

2. 'Note on the Occurrence of Keisley-Limestone Pebbles in the Red Sandstone-Rocks of Peel (Isle of Man).' By E. Leonard Gill, Esq., B.Sc. (Communicated by Prof. W. Boyd Dawkins, D.Sc., F.R.S., F.S.A., F.G.S.)

In addition to the photographs mentioned above, the following specimens were exhibited:—

Rock-Specimens (Pebbles) and Microscope-Slides, exhibited by O. A. Shrubsole, Esq., F.G.S., in illustration of his paper.

April 29th, 1903.

J. J. Harris Teall, Esq., M.A., F.R.S., Vice-President, in the Chair.

Norman Melville Kirkcaldy, Esq., C.E., Dunedin (New Zealand); and Bernard Stracey, Esq., M.B., Sutton Bonnington, near Loughborough, were elected Fellows; and Prof. Carl Klein, of Berlin, was elected a Foreign Correspondent of the Society.

The List of Donations to the Library was read.

Prof. Bonney, in exhibiting three specimens found by Prof. Collie, F.R.S., on Desolation-Valley Glacier, east of the watershed of the Rocky Mountains and a little south of the Canadian Pacific Railway, pointed out that one, a slab of white quartzite, was covered by horizontal worm-burrows, often about one-third of an inch in

diameter, such as those named *Planolites* by Nicholson; another, of the same material, had blunt ridges, tapering to a point, an inch or so long, rudely parallel, in sets of about four. These he should have taken for the tracks of a (?) crustacean, but they were single, not paired, and without any sign of a medial furrow. The third was a slab, measuring about 11 by 5 inches and $1\frac{1}{2}$ inches thick, of a brownish quartzite passing quickly on one side into a green argillite, the other side being thickly studded with dome-like eminences about an inch in diameter, and nearly half this in height. Most of them show a slight 'dimple' at the top, and a very slight 'step' or swelling often forms a sort of ring part way up the dome. Some argillite, like that on the other side, remains about their bases, and a few tracks of *Planolites* wind among them, and once or twice seem to pass over them. The domes are formed of a quartzite, identical with that of the slab. It shows a very faint stratification, and consists of grains of quartz, not seldom well rounded, embedded in a minutely-micaceous matrix, probably an alteration-product of felspar. They cannot be concretions; so the speaker regarded them as the casts of pits in the argillite, made by a large annelid, which retreated into it vertically (*? Scolithus*), afterwards filled up by a layer of sand.

The following communications were read:—

1. 'The Age of the principal Lake-Basins between the Jura and the Alps.' By Charles S. Du Riche Preller, M.A., Ph.D., A.M.I.C.E., M.I.E.E., F.R.S.E., F.G.S.

2. 'On a Shelly Boulder-Clay in the so-called Palagonite-Formation of Iceland.' By Helgi Pjetursson, Cand. Sci. Nat. (Communicated by Prof. W. W. Watts, M.A., M.Sc., Sec.G.S.)

In addition to the specimens described above, the following were exhibited:—

Specimens of Alpine Rocks from the Zurich Gravel-Beds, exhibited by Dr. C. S. Du Riche Preller, M.A., F.R.S.E., F.G.S., in illustration of his paper.

The following donations were also laid on the table:—

A series of Fossil Brachiopoda illustrating the paper read on February 4th, 1903, by G. W. Lamplugh, Esq., F.G.S., & J. F. Walker, Esq., M.A., F.L.S., F.G.S., 'On a Fossiliferous Band at the Top of the Lower Greensand at Shenley Hill, near Leighton Buzzard (Bedfordshire),' presented by the Authors.

A sample of Volcanic Ash which fell on Barbados between 11 A.M. and 5 P.M. on Sunday, March 22nd, 1903, as the result of an eruption of the St. Vincent Soufrière on that day. Collected at Chelston, Bridgetown. Presented by Sir D. Morris, K.C.M.G., Imperial Commissioner of Agriculture for the West Indies.

Topographical Map of Switzerland, on the scale of 1 : 200,000, presented by Dr. C. S. Du Riche Preller, M.A., F.R.S.E., F.G.S.

May 13th, 1903.

Edwin Tulley Newton, Esq., F.R.S., Vice-President, in the Chair.

John Frederick Charles Abelspies, Esq., Assoc.Inst. M. & M., Charlestown (Cornwall); and William Henry Sutcliffe, Esq., Shore, Littleborough (Lancashire), were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'On some Disturbances in the Chalk near Royston (Hertfordshire).' By Horace Bolingbroke Woodward, Esq., F.R.S., F.G.S.

2. 'On a Section at Cowley, near Cheltenham, and its Bearing on the Interpretation of the Bajocian Denudation.' By Linsdall Richardson, Esq., F.G.S.

3. 'Description of a Species of *Heterastræa* from the Lower Rhætic of Gloucestershire.' By Robert F. Tomes, Esq., F.G.S.

The following specimens were exhibited:—

Specimens of Weathered Chalk grooved by Rain and of Glaciated Chalk from Boulder-Clay, exhibited by Horace B. Woodward, Esq., F.R.S., F.G.S., in illustration of his paper.

Specimens of 'Bored Bed' of the Bajocian Denudation in the Cheltenham District, exhibited by L. Richardson, Esq., F.G.S., in illustration of his paper.

Specimen of *Heterastræa* from the Lower Rhætic, near Tewkesbury, exhibited by R. F. Tomes, Esq., F.G.S., in illustration of his paper.

May 27th, 1903.

Edwin Tulley Newton, Esq., F.R.S., Vice-President, in the Chair.

David C. Evans, Esq., St. Clears (Caermarthenshire), and William Alvara Humphrey, Esq., B.A., Cape Town (South Africa), were elected Fellows of the Society.

The List of Donations to the Library was read.

The Secretary read a letter from the President, expressing his regret that he would be unable to preside at the remaining meetings of the Session, as, in obedience to the orders of his doctor, he was obliged to take a complete holiday from all work for the next few weeks.

It was announced that the Council had awarded the Proceeds of the Daniel Pidgeon Fund for 1903 to Dr. Ernest Willington Skeats, F.G.S., of the Royal College of Science, South Kensington.

The following communications were read:—

1. 'An Experiment in Mountain-Building.' By the Right Hon. the Lord Avebury, P.C., D.C.L., LL.D., F.R.S., F.G.S.

2. 'The Toarcian of Bredon Hill (Worcestershire), and a Comparison with Deposits elsewhere.' By S. S. Buckman, Esq., F.G.S.

3. 'Two Toarcian Ammonites.' By S. S. Buckman, Esq., F.G.S.

The following specimens and map were exhibited:—

A Series of Casts, exhibited by the Right Hon. the Lord Avebury, P.C., D.C.L., LL.D., F.R.S., F.G.S., in illustration of his paper.

A copy of the new lithographed issue of Sheet 156 (n. s.) of the Geological Survey 1-inch Map of Leicester (Drift) by C. Fox-Strangways, presented by the Director of H.M. Geological Survey.

June 10th, 1903.

J. J. Harris Teall, Esq., M.A., F.R.S., Vice-President, in the Chair.

The Names of certain Fellows of the Society were read out for the first time, in conformity with the Bye-Laws, Sect. VI. Art. 5, in consequence of the non-payment of the Arrears of their Contributions.

The List of Donations to the Library was read.

The following communications were read:—

1. 'On Primary and Secondary Devitrification in Glassy Igneous Rocks.' By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S., and John Parkinson, Esq., F.G.S.

2. 'Geology of the Ashbourne & Buxton Branch of the London & North-Western Railway:—Crake Low to Parsley Hay.' By Henry Howe Arnold-Bemrose, Esq., M.A., F.G.S.

The following specimens, etc. were exhibited:—

Microscopic Rock-Sections of Glassy Igneous Rocks, exhibited by Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S., and John Parkinson, Esq., F.G.S., in illustration of their paper.

Specimens, Microscopic Rock-Sections, Photographs and Lantern-Slides, exhibited by H. H. Arnold-Bemrose, Esq., M.A., F.G.S., in illustration of his paper.

Specimens from the Rhætic Bone-Bed and the Upper Rhætic of Garden Cliff, Westbury-on-Severn, exhibited by W. F. Gwinnell, Esq., F.G.S.

June 24th, 1903.

Sir Archibald Geikie, D.Sc., LL.D., F.R.S., Vice-President, in the Chair.

Capt. Charles Braithwaite Wallis, J.P., F.R.G.S., Junior Army & Navy Club, St. James's Street, S.W., was elected a Fellow; and Dr. Emil Ernst August Tietze, of Vienna, was elected a Foreign Correspondent, of the Society.

The Names of certain Fellows of the Society were read out for the second time, in conformity with the Bye-Laws, Sect. VI, Art. 5, in consequence of the non-payment of the Arrears of their Contributions.

The List of Donations to the Library was read.

Mr. Horace B. Woodward exhibited five Lantern-Slides of the Disturbed Chalk near Royston, observing that since he had had the honour of reading his paper before the Society, he had conducted an excursion of the Geologists' Association to the localities described; and that Mr. J. J. H. Teall, F.R.S., who had taken several photographs on that occasion, had very kindly made lantern-slides of them.

The following communications were read:—

1. 'On a Transported Mass of Ampthill Clay in the Boulder-Clay at Biggleswade (Bedfordshire).' By Henry Home, Esq. (Communicated by Horace B. Woodward, Esq., F.R.S., F.G.S.)

2. 'The Rhætic and Lower Lias of Sedbury Cliff, near Chepstow.' By Linsdall Richardson, Esq., F.G.S.

3. 'Notes on the Lowest Beds of the Lower Lias at Sedbury Cliff.' By Arthur Vaughan, Esq., B.A., B.Sc., F.G.S.

The following specimens were exhibited:—

Specimens from Biggleswade (Bedfordshire), exhibited in illustration of the paper by H. Home, Esq.

Specimens exhibited by L. Richardson, Esq., F.G.S., in illustration of his paper.

Specimens exhibited by A. Vaughan, Esq., B.A., B.Sc., F.G.S., in illustration of his paper.

THE

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THE GEOLOGICAL SOCIETY OF LONDON.

Vol. LIX.

1. *The* Fossil Flora *of the* Cumberland Coalfield, *and the* Palæobotanical Evidence *with regard to the* Age *of the* Beds. By E. A. Newell Arber, Esq., M.A., F.G.S., Trinity College, Cambridge; University Demonstrator in Palæobotany. (Read November 5th, 1902.)

[Plates I & II.]

Contents.

I. Introduction.

The most important area of the Cumberland Coalfield is situated on, or near, the western coast-line, extending from the neighbourhood of Whitehaven on the south to that of Maryport on the north. The geology of this district was first studied by Sedgwick, and has since formed the subject of numerous memoirs, to many of which reference will here be made. In this paper, however, we are only

concerned with the physical and stratigraphical geology of the Cumberland Coalfield, in regard to the horizons from which plant-remains have been obtained, and the evidence which these plants present as to the age of the different beds.

The succession of Upper Carboniferous rocks in the region in question is apparently twofold: an essentially arenaceous series, overlying argillaceous and carbonaceous deposits.[1]

The arenaceous series, of at present unknown vertical extent, but which is at least 600 feet thick, consists of yellowish-grey, red, or purple, massive sandstones, alternating with beds of shale and fireclay of secondary importance. Thin bands of coal and hæmatite also often occur. This series is typically developed in the immediate neighbourhood of Whitehaven, as well as in other parts of the district, and is commonly known as the Whitehaven Sandstone. The term 'Whitehaven Sandstone' has, however, been applied, on grounds which are not entirely satisfactory, to rocks of somewhat similar lithological composition in other districts. I propose, therefore, to speak of this series, as developed in this area of the Cumberland Coalfield, as the Sandstone Series.

The carbonaceous deposits, lying below the Sandstone Series, are at least 1300 feet thick,[2] but here again there is some doubt as to the vertical extent of the series, since the base has not so far been definitely determined.[3] It consists essentially of argillaceous material, containing many seams of coal, often of considerable thickness. These form the productive portion of the Cumberland Coalfield, and are extensively worked in the district in question. Some arenaceous deposits also occur in this series, especially in the lower portions, where this type of rock seems to increase in importance in several localities. The whole of these beds below the Sandstone Series are locally known as the Coal-Measures, or Lower Coal-Measures, but I prefer to speak of them for the present as the Productive Measures, in order to avoid any imputation as to age or horizon; questions which, so far, have not been established on a satisfactory or definite basis.

By almost every observer, from Sedgwick onward, the Sandstone Series has been stated to overlie the Productive Measures unconformably, and this is maintained nowadays by those who are engaged in working the Productive Measures in this district.[4]

[1] J. D. Kendall (96) p. 205, etc.; also *id.* (83) p. 321. The numerals in parentheses after the authors' names indicate the year of publication of the paper, to which reference will be found in the Bibliography on p. 21.

[2] J. D. Kendall (83) pp. 347–48 & (96) p. 212.

[3] See p. 20.

[4] Special reference to the unconformity will be found in Sedgwick (32) p. 344, Holmes (96) p. 406, & Kendall (96). So far as I am aware this has only been disputed by Mr. Strahan, on the ground that there was no definite base to the Sandstone Series; see J. D. Kendall (95) Discussion, p. 236, and *id.* (96) p. 205. Personally, I have had no opportunity of studying the junction of the Sandstone Series and Productive Measures in the field, and can therefore offer no observations on this point.

II. The Fossil Flora of the Cumberland Coalfield.

A. The Sandstone Series.

The Sandstone Series may be typically studied in the sea-cliffs immediately north and south of Whitehaven. The series has there been largely denuded, and the uppermost beds are not present.

The upper portion of the Sandstone Series was recognized in 1891 by the late Mr. Brockbank,[1] in a section at Frizington Hall, some 3 miles to the east of Whitehaven. The upper beds were there found to contain bands of *Spirorbis*-Limestone, and were overlain by 20 feet of Permian Brockram. Further reference will be made to this important section, in considering the evidence as to the age of the Sandstone Series.

The Sandstone Series is also overlain by Permian rocks at the Croft Pit of the Whitehaven Colliery Company, $1\frac{1}{2}$ or 2 miles south of Whitehaven, and possibly in other localities. There are few exposures, if any, of these beds at the present time, and only one fossil plant[2] has, so far as I can ascertain, been collected from the Upper Division of the Sandstone Series.

The sandstone forming the cliffs along the coast to the north and south of Whitehaven belongs,[3] as will be shown here, to the Lower Division of the Sandstone Series, and may be spoken of as such. Sections of the coast-line were given by Sedgwick[4] in 1836, and by Dunn[5] in 1860. To the north of Whitehaven that portion of Bransty Cliff, which extends from the William Pit to the Countess or Lamb-Hill Pit,[6] consists of yellowish-grey, or whitish freestones, with alternations of shale and other argillaceous rocks, and thin bands of hæmatite and coal. The beds dip south-westward. The cliff probably averages considerably more than 100 feet in height, and at the William Pit, Whitehaven, the Sandstone Series is believed to extend to 120 feet below sea-level. The total thickness of the Sandstone Series here may be taken as at least 200 feet, if not more.

(1) Localities and Horizons of Plant-Remains.

A considerable number of plant-remains were collected from the Lower Sandstone Series of Bransty Cliff. The friable arenaceous shales, alternating with the massive freestones, are full of plant-impressions. The average height of the different shale-bands, from which the specimens were collected, may be taken as 50 to 80 feet above the base of the Sandstone Series. The sandstone itself,

[1] W. Brockbank (91) p. 422.

[2] This is a single pinnule of a fern-like plant, *Neuropteris*, in the possession of Mr. J. D. Kendall, F.G.S.; and was obtained by him at Millyeat. I am indebted to Mr. Kendall for an opportunity of seeing this specimen, and for much information on the Whitehaven district.

[3] W. Brockbank (91) p. 420.

[4] A. Sedgwick (36) pl. xxv, fig. 1. [5] M. Dunn (60).

[6] This is the first pit along the shore, north of the William Pit, and rather more than half a mile from it.

especially near the Countess Pit, contains many fragments of plants, some of which are sufficiently well preserved to admit of identification. The bands of impure fireclay also contain plant-remains.

Besides the plants which I have collected in this locality, there are two other collections in the Woodwardian Museum at Cambridge, one of which is without doubt derived from the Sandstone Series.

The earliest reference to fossil plants from the Upper Carboniferous rocks of Whitehaven is that by John Woodward in his 'Catalogue of English Fossils,' published in 1729. Woodward[1] there mentions, or describes, twenty-four plant-remains from

'a dark grey slatey Stone . . . at the depth of about 25 Fathom, in Bransty-Cliff, by the Duke of Somerset's Salt-Pans, near Whitehaven.'

These specimens are preserved with the rest of Woodward's historic collections in the Museum which bears his name, at Cambridge. The following is a list of the species from Whitehaven:—

Calamites (Eucalamites) ramosus, Art.	*Neuropteris obliqua* (Brongt.).
Calamocladus equisetiformis (Schl.).	*Mariopteris (Diplothmema) muricata* (Schl.).
Neuropteris Scheuchzeri, Hoffm.	

The exact locality, and consequently the horizon of Woodward's plants, cannot, despite his full record, be definitely ascertained now.[2] While there seems to me to be very little doubt that these specimens were obtained from the Sandstone Series, I have excluded this collection from the evidence as to the age of the beds in this district, on account of the uncertainty as to the series and horizon from which they were obtained. The opportunity has, however, been taken to figure two of them, *Neuropteris Scheuchzeri* and *N. obliqua* (Pl. I, figs. 1 & 2).

Among the large collection of Palæozoic plant-remains in the Woodwardian Museum, there are several specimens from the Sandstone Series at Whitehaven. These were collected by Sedgwick during his study of this district, and are mentioned by him in his memoirs on the Cumberland Coalfield, read before the Geological Society more than sixty years ago. In 1831[3] he stated that

'traces of vegetable fossils occur in this deposit, on the coast of Cumberland, near Whitehaven.'

Ten years later[4] he further stated that

'the flora of the Coalfield existed apparently in full perfection during the period of the Lower . . . Red Sandstone,'

and that he had obtained many new specimens of this flora. Sedgwick obtained his specimens on the coast at Whitehaven itself. Speaking of the Sandstone Series in 1832, he says:—

'It is generally without any trace of fossils: the very extensive excavations carried on in it on both sides of Whitehaven, have, however, brought to light a few obscure impressions of *Equiseta* and *Calamites*.'[5]

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[1] J. Woodward (1729) pt. ii, p. 16.

[2] At a distance of less than a mile along Bransty Cliff from Whitehaven, the Productive Measures are faulted up against the Sandstone Series.

[3] A. Sedgwick (35) p. 58, footnote.

[4] *Id.* (42) p. 545.

[5] *Id.* (36) p. 395.

The remaining locality from which plant-remains were collected by me is the coal of the Senhouse High Band, at the Ellenborough Colliery, south of Maryport. This seam of coal, which is here of workable thickness, contains numerous impressions of *Sigillaria* and *Stigmaria*. It belongs to the Sandstone Series.[1]

No other plants from the Sandstone Series are apparently to be found in any museum or private collection, apart from those above mentioned in the Woodwardian Museum. I have made many enquiries for specimens in the museums in the North of England, and in London, and also of nearly all those who from time to time have studied the Carboniferous rocks in this district. Several geologists[2] were aware that such plant-remains had been found, but were unable to give particulars of the whereabouts of any specimens.

(2) The Flora of the Lower Division of the Sandstone Series.[3]

Equisetales.

CALAMITES, Suckow, 1784.

Acta Acad. Theod. Palat. vol. v, p. 355.

1. CALAMITES (CALAMITINA) APPROXIMATUS, Brongt. (Pl. I, fig. 3.)

Woodwardian Mus. Camb., Carboniferous Plant Coll. Nos. 416–18, 420, 851, etc. (Sedgwick Collection.)
Locality.—The coast at Whitehaven.

Calamites approximatus.
1828. Brongniart, 'Hist. des Végét. foss.' pl. xxiv, figs. 2–5.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 33.
1899. Potonié, 'Lehrb. d. Pflanzenpal.' p. 191, fig. 187.
Calamitina approximata.
1892. Kidston, Trans. Roy. Soc. Edinb. vol. xxxvii, pt. ii, p. 311 & pl. ii, figs. 5–6.
1901. Kidston, Proc. Yorks. Geol. & Polytechn. Soc. n. s. vol. xiv, pl. xxxv, fig. 2.
Calamites (Calamitina) approximatus, Brongt.
1884. Weiss, Abhandl. Geol. Specialk. Preussen, vol. v, pt. ii, p. 81 & pl. xxv, fig. 1.
1898. Seward, 'Fossil Plants' vol. i, pp. 369–70 & fig. 100.

Calamitean pith-casts are very common fossils in the Sandstone Series of Whitehaven, and among the specimens in Sedgwick's Collection some are exceedingly well preserved. The cast of *C. approximatus*, part of which is figured on Pl. I, fig. 3, is 4 inches long, and $2\frac{1}{2}$ inches across. There are eight small internodes, each about a quarter of an inch long, succeeded by a larger internode, $\frac{5}{8}$ inch in length. The latter bears a row of branch-scars, some of which are seen distinctly in the photograph. Other specimens show twelve small internodes, of approximately equal length, between the larger internodes bearing the branch-scars.

[1] J. D. Kendall (83) p. 344 & (96) p. 212.
[2] *Id.* (79) p. 115 & (96) p. 204.
[3] The full synonymy, previous to 1886, will be found in most cases in Kidston's Catalogue of Palæozoic Plants in the British Museum. Only the more recent references, and some of the best-known works in which the species are figured, are mentioned here.

2. Calamites (Calamitina) varians, Sternb.

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 852–53. (Sedgwick Collection.)
Locality.—The coast at Whitehaven.

Calamites approximatus.
1828. Brongniart, 'Hist. des Végét. foss.' pl. xv, figs. 7 & 8, & pl. xxiv, fig. 1.
Calamites varians.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 31.
1899. Potonié, 'Lehrb. d. Pflanzenpal.' p. 197, fig. 193.
Calamites (Calamitina) varians, Sternb.
1884. Weiss, Abhandl. Geol. Specialk. Preussen, vol. v, pt. ii, p. 63, pl. xxv, fig. 2, pl. xxvii, fig. 2, & pl. xxviii, figs. 1–2 & 4.

3. Calamites (Stylocalamites) Suckowi, Brongt.

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 891–93.
Locality.—Bransty Cliff, Whitehaven.

Calamites Suckowi.
1828. Brongniart, 'Hist. des Végét. foss.' p. 124, pl. xiv, fig. 6, pl. xv, figs. 1–6, & pl. xvi, figs. 2–4.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 24.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 333, pl. liv, figs. 2–3 & pl. lv, fig. 1.
1899. Potonié, 'Lehrb. d. Pflanzenpal.' p. 195, figs. 188 (1) & 189.
1900. Zeiller, 'Élém. de Paléobot.' p. 151 & fig. 106 [on p. 149].
1901. Kidston, Proc. Yorks. Geol. & Polytechn. Soc. n. s. vol. xiv, pl. xxx, fig. 1 & pl. xxxv, fig. 3.
Calamites (Stylocalamites) Suckowi, Brongt.
1884. Weiss, Abhandl. Geol. Specialk. Preussen, vol. v, pt. ii, p. 129, pl. ii, fig. 1, pl. iii, figs. 2–3, pl. iv, fig. 1, pl. xvii, fig. 4, & pl. xxvii, fig. 3.
1898. Seward, 'Fossil Plants' vol. i, p. 374 & fig. 82 [on p. 323].

4. Calamites (Stylocalamites) Cisti, Brongt.

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 894–96, & ? 856 & 858. (Sedgwick Coll. in part.)
Locality.—Bransty Cliff, Whitehaven.

Calamites Cisti.
1828. Brongniart, 'Hist. des Végét. foss.' pl. xx.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 30.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 342 & pl. lvi, figs. 1–2.

Calamocladus, Schimper, 1869.

'Traité Pal. végét.' vol. i, p. 323.

Calamocladus equisetiformis (Schl.).

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 898–99.
Locality.—Bransty Cliff, Whitehaven.

Hippurites longifolia.
1831–37. Lindley & Hutton, 'Foss. Flora' vol. iii, pls. cxc & cxci.
Calamocladus equisetiformis.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 38.
1898. Seward, 'Fossil Plants' vol. i, p. 335, fig. 87.
1901. Kidston, Proc. Yorks. Geol. & Polytechn. Soc. n. s. vol. xiv, pl. xxx, fig. 3.
Asterophyllites equisetiformis.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 368 & pl. lviii, figs. 1–7.
1900. Zeiller, 'Élém. de Paléobot.' p. 161, fig. 113.

Annularia, Sternberg, 1820.

'Versuch einer geogn.-botan. Darstell. d. Flora d. Vorwelt' pt. i, fasc. ii, p. 32.

Annularia sphenophylloides (Zenker).

Woodwardian Mus. Camb., Carb. Plant Coll. No. 932.
Locality.—Bransty Cliff, Whitehaven.

Annularia sphenophylloides.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 44.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 388 & pl. lx, figs. 5–6.
1898. Seward, 'Fossil Plants' vol. i, p. 341, fig. 89.
1900. Zeiller, 'Élém. de Paléobot.' p. 163, fig. 114.
1901. Kidston, Proc. Yorks. Geol. & Polytechn. Soc. n. s. vol. xiv, pl. xxxvii, fig. 1.
Annularia brevifolia.
1900. Scott, 'Studies in Fossil Botany' p. 69, fig. 31.

Sphenophyllales.

Sphenophyllum, Brongniart, 1828.

'Prodr. Hist. des Végét. foss.' p. 68.

Sphenophyllum cuneifolium (Sternb.).

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 928–29.
Locality.—Bransty Cliff, Whitehaven.

Sphenophyllum cuneifolium.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 48.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 413, pl. lxii, fig. 1 & pl. lxiii, figs. 1–10.
1893. Zeiller, Mém. Soc. géol. France, Paléont. Mém. No. 11, vol. iv, p. 12, pl. i, figs. 1–4, pl. ii, figs. 1–3, & pl. iii, figs. 1–2.
1898. Seward, 'Fossil Plants' vol. i, p. 402.
1899. Zeiller, Mém. Soc. géol. France, Paléont. Mém. No. 21, vol. viii, p. 56 & pl. vi, figs. 6–7.
1900. Zeiller, 'Élém. de Paléobot.' p. 139, fig. 100.
1901. Kidston, Trans. Nat. Hist. Soc. Glasgow, n. s. vol. vi, p. 124, fig. 21 (*a* & *b*).
Sphenophyllum erosum.
1831–37. Lindley & Hutton, 'Foss. Flora' vol. i, pl. xiii.

Lycopodiales.

Lepidodendron, Sternberg, 1820.

'Versuch einer geogn.-botan. Darstell. d. Flora d. Vorwelt,' pt. i, fasc. i, p. 23.

Lepidodendron aculeatum, Sternb. (Pl. I, fig. 4.)

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 47, 48, etc. (Sedgwick Coll.)
Locality.—The coast at Whitehaven.

Lepidodendron aculeatum.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 153.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 435 & pl. lxv, figs. 1–7.
1899. Potonié, 'Lehrb. d. Pflanzenpal.' p. 220, fig. 211.
1899. Zeiller, Mém. Soc. géol. France, Paléont. Mém. No. 21, vol. viii, p. 72 & pl. vi, fig. 9.
1900. Zeiller, 'Élém. de Paléobot.' p. 180, fig. 123.
1901. Kidston, Trans. Nat. Hist. Soc. Glasgow, n. s. vol. vi, p. 44, figs. 3–4.

The majority of the specimens in Sedgwick's Collection are the remains of *Lepidodendra*. Most of them are more or less decorticated. Some of the least decorticated probably belong to *Lepidodendron aculeatum,* while others, perhaps, belong to species that cannot be definitely identified. Fortunately there are one or two well-preserved examples of the former, of which one is figured in Pl. I, fig. 4. The whole specimen measures 8 by 6 inches. The leaf-bases average $1\frac{1}{2}$ inches in length, and $\frac{5}{8}$ inch across at the widest part. The prints of the bundle, and of the parichnos of the leaf-scar, are well preserved in some of these leaf-bases.

Lepidophloios, Sternberg, 1820.

'Versuch einer geogn.-botan. Darstell. d. Flora d. Vorwelt,' pt. i, fasc. iv, p. 13.

Lepidophloios (Halonia) sp.

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 43 & 189. (Sedgwick Coll.)
Locality.—The coast at Whitehaven.

Cf. *Halonia regularis.*
1831–37. Lindley & Hutton, 'Foss. Flora' vol. iii, pl. ccxxviii.
1872. Binney, Monogr. Palæont. Soc. 'Obs. Struct. Foss. Plants' pt. iii, p. 94 & pl. xviii.

Lepidophyllum, Brongniart, 1828.

'Prodr. Hist. des Végét. foss.' p. 87.

Lepidophyllum sp.

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 930 & 946.
Locality.—Bransty Cliff, Whitehaven.

Sigillaria, Brongniart, 1822.

'Sur la Classif. des Végét. foss.' Mém. Mus. Hist. Nat. vol. viii, p. 209.

1. Sigillaria scutellata, Brongt. (Pl. I, fig. 5.)

Woodwardian Mus. Camb., Carb. Plant Coll. No. 860. (Sedgwick Coll.)
Locality.—The coast at Whitehaven.

Sigillaria scutellata.
1828. Brongniart, 'Hist. des Végét. foss.' p. 455, pl. cl, figs. 2–3 & pl. clxiii, fig. 3.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 533, pl. lxxxii, figs. 1–6 & 9.
1899. Zeiller, Mém. Soc. géol. France, Paléont. Mém. No. 21, vol. viii, p. 77 & pl. vi, fig. 18.
1900. Zeiller, 'Élém. de Paléobot.' p. 191, fig. 133.

The only *Sigillaria* among Sedgwick's Whitehaven plants is fortunately a well-preserved specimen, which is figured in Pl. I, fig. 5. Five ribs are shown with three to five leaf-scars on each, which are distant $\frac{5}{8}$ inch one from the other. The folds below the scars, which form one of the characteristics of this species, are also clearly indicated. The specimen measures 4×2 inches.

2. Sigillaria ovata, Sauveur.

Woodwardian Mus. Camb., Carb. Plant Coll. No. 901.
Locality.—Senhouse High Band, Ellenborough Colliery, Ellenborough.

Sigillaria ovata.
1848. Sauveur, 'Végét. foss. Terr. houill. de la Belgique' pl. li, fig. 2.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 522 & pl. lxxix, figs. 4–7.
Sigillaria Essenia.
1880–84. Achepohl, 'Niederrh.-Westfal. Steinkohlengeb.' p. 118 & pl. xxxvi, fig. 9.

3. Sigillaria lævigata, Brongt.

Woodwardian Mus. Camb., Carb. Plant Coll. No. 901.
Locality.—Senhouse High Band, Ellenborough Colliery, Ellenborough.

Sigillaria lævigata.
1828. Brongniart, 'Hist. des Végét. foss.' p. 471 & pl. cxliii.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 192.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 519 & pl. lxxviii, figs. 1–4.
1887. Kidston, Trans. Roy. Soc. Edinb. vol. xxxiii, pt. ii, p. 398 & pl. xxviii, fig. 5.

Stigmaria, Brongniart, 1822.

'Sur la Classif. des Végét. foss.' Mém. Mus. Hist. Nat. vol. viii, p. 209.

Stigmaria ficoides (Sternb.).

Woodwardian Mus. Camb., Carb. Plant Coll. No. 900.
Locality.—Senhouse High Band, Ellenborough Colliery, Ellenborough.

Stigmaria ficoides.
1831–37. Lindley & Hutton, 'Fossil Flora' vol. i, pls. xxxi–xxxvi & vol. iii, pl. clxvi.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 201.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 611 & pl. xci, figs. 1–6.
1887. Williamson, Palæont. Soc. 'Monogr. on *Stigmaria ficoides*' pls. i–xv.
1899. Potonié, 'Lehrb. d. Pflanzenpal.' p. 209, figs. 202–203.
1900. Zeiller, 'Élém. de Paléobot.' p. 200, fig. 139.
1901. Kidston, Trans. Nat. Hist. Soc. Glasgow, n. s. vol. vi, p. 66, fig. 11.

Filicales.

Sphenopteris, Brongniart, 1822.

'Sur la Classif. des Végét. foss.' Mém. Mus. Hist. Nat. vol. viii, p. 233.

Sphenopteris obtusiloba, Brongt.

Woodwardian Mus. Camb., Carb. Plant Coll. No. 931.
Locality.—Bransty Cliff, Whitehaven.

Sphenopteris obtusiloba.
1828. Brongniart, 'Hist. des Végét. foss.' p. 204 & pl. liii, fig. 2*.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 68.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 65, pl. iii, figs. 1–4, pl. iv, fig. 1, & pl. v, figs. 1–2.
1899. Potonié, 'Lehrb. d. Pflanzenpal.' p. 137, fig. 131.
1900. Zeiller, 'Élém. de Paléobot.' p. 82, fig. 51.
1901. Kidston, Proc. Yorks. Geol. & Polytechn. Soc. n. s. vol. xiv, pl. xxv, fig. 1.

Neuropteris, Brongniart, 1822.

'Sur la Classif. des Végét. foss.' Mém. Mus. Hist. Nat. vol. viii, p. 233.

1. Neuropteris tenuifolia (Schl.).

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 933, 935–36, & 939–41.
Locality.—Bransty Cliff, Whitehaven.

Filicites tenuifolius.
1820–23. Schlotheim, 'Petrefactenk.' p. 405 & pl. xxii, fig. 1.
Neuropteris tenuifolia.
1828. Brongniart, 'Hist. des Végét. foss.' p. 241 & pl. lxxii, fig. 3.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 273 & pl. xlvi, fig. 1.

This species is very common in the shaly bands of the lower portion of the Sandstone Series.

2. Neuropteris Scheuchzeri, Hoffm. (Pl. I, fig. 1.)

Woodwardian Mus. Camb., Carb. Plant Coll. No. 934.
Locality.—Bransty Cliff, Whitehaven.

Neuropteris Scheuchzeri.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 95.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 251 & pl. xli, figs. 1–3.
1887. Kidston, Trans. Roy. Soc. Edinb. vol. xxxiii, pt. ii, p. 356 & pl. xxiii, figs. 1–2.
1899. Zeiller, Mém. Soc. géol. France, Paléont. Mém. No. 21, vol. viii, p. 43 & pl. iv, fig. 9.

The specimen figured is from the Woodward Collection. It shows a perfect, detached pinnule of a frond. The same species was also found by me in the above locality.

Alethopteris, Sternberg, 1820.

'Versuch einer geogn.-botan. Darstell. d. Flora d. Vorwelt' pt. i, fasc. iv, p. xxi.

Alethopteris Serli (Brongt.).

Woodwardian Mus. Camb., Carb. Plant Coll. No. 937.
Locality.—Bransty Cliff, Whitehaven.

Pecopteris Serli.
1828. Brongniart, 'Hist. des Végét. foss.' p. 292 & pl. lxxxv.
1831–37. Lindley & Hutton, 'Foss. Flora' vol. iii, pl. ccii.
Alethopteris Serli.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 135.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 234, pl. xxxvi, figs. 1–2 & pl. xxxvii, figs. 1–2.
1900. Zeiller, 'Élém. de Paléobot.' p. 95, fig. 68.

Cordaitales.

Cordaites, Unger, 1850.

'Genera & Species Plantarum fossilium' p. 277.

1. Cordaites principalis (Germar).

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 942–45.
Locality.—Bransty Cliff, Whitehaven.

Cordaites principalis.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 207.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 629, pl. xciii, fig. 3 & pl. xciv, fig. 1.

2. Cordaites sp.

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 725–28. (Sedgwick Coll.)
Locality.—The coast at Whitehaven.

Sternbergia approximata.
1831–37. Lindley & Hutton, 'Foss. Flora' vol. iii, pls. ccxxiv & ccxxv.
Sternbergia.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 221.
Artisia approximata.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 634 & pl. xciv, figs. 2–3.
[*Dadoxylon approximatum.*]
1851. Williamson, Mem. Lit. & Phil. Soc. Manch. ser. 2, vol. ix, p. 340 & figs. 1–11.
Cordaites.
1899. Potonié, 'Lehrb. d. Pflanzenpal.' pp. 266–67, fig. 253.

B. The Productive Measures.

The Productive Measures contain three great coal-seams, which form the most important horizons in the Cumberland Coalfield from the economic standpoint. They are, for the most part, of constant thickness, and are easily traced throughout the district, although known locally under different names.[1] The thickest seam is known at Whitehaven as the 'Main Band,' and is there 10 feet thick. At the William Pit, Whitehaven, it lies 455 feet below the base of the Sandstone Series, and 576 feet from the surface. In the northern portion of the area, in the neighbourhood of Maryport, this seam is split into an upper, or 'Metal Band,' and a lower,

[1] J. D. Kendall (83) p. 340.

the 'Cannel Band.' The 'Bannock Band,' another important seam, lies about 135 feet above the Main Band at Whitehaven, and is there 7 to 8 feet thick. The 'Six Quarters Coal' at Whitehaven is about 255 feet below the Main Band, and $7\frac{1}{2}$ feet thick.

(1) Localities and Horizons of Plant-Remains.

Fossil plants do not appear to be so abundant in the Cumberland Coalfield as in some other coalfields. The finest plants collected were from the Cannel Band in the Robin Hood Pit at Flimby, south of Maryport, belonging to the Flimby & Broughton-Moor Coal Company. I am indebted to Mr. Lloyd Wilson, of the above Company, for special facilities for obtaining this collection. The plants occur there in the shales forming the roof of the Cannel Coal, from 3 inches to 2 feet above the seam. This band is believed to lie about 380 feet below the Sandstone Series.[1]

I also obtained plants from the shales above the Main Band at Walk Mill Pit, Moresby, rather more than 2 miles east of Whitehaven. A few specimens, from the same horizon in the William Pit at Whitehaven, were forwarded to me by the kindness of the manager, Mr. Turner.

All the plants from the Productive Series are thus from the horizon of the Main Band, which, as will be shown, belongs to the Upper Division of the Productive Measures. Attempts have been made to obtain specimens from the Bannock Band, and especially from seams below the Main Band, but without success.

So far as I am aware, with the exception of a few specimens at Keswick and Oxford, mostly without record of horizons, no collection from the Productive Measures of Cumberland is to be found in any museum. The only specimens that have been described and figured from the Whitehaven Coalfield are Lindley & Hutton's *Sphenopteris crenata* and *Schizopteris adnascens*[2]; the types of these are in the Museum of the Northumberland & Durham Natural History Society at Newcastle-on-Tyne. Mr. Kidston has shown that both Lindley & Hutton's species belong to *Pecopteris (Dactylotheca) plumosa*, Art.[3]

(2) The Flora of the Upper Division of the Productive Measures.

Equisetales.

Calamites.

1. Calamites (Calamitina) varians, Sternb. (See p. 6.)

Woodwardian Mus. Camb., Carb. Plant Coll. No. 911.
Locality.—Above the Cannel Band, Robin Hood Pit, Flimby.

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[1] From information supplied by the above-mentioned Company.
[2] J. Lindley & W. Hutton (31) vol. ii, pls. c & ci. I am indebted to Mr. Kidston for calling my attention to this fact.
[3] R. Kidston (94) p. 245.

2. CALAMITES (STYLOCALAMITES) SUCKOWI, Brongt. (See p. 6.)

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 911 & 905.
Localities.—Above the Cannel Band, Robin Hood Pit, Flimby; above the Main Band, Walk Mill Pit, Moresby.

3. CALAMITES (STYLOCALAMITES) CISTI, Brongt.? (See p. 6.)

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 906 & 960.
Localities.—Above the Main Band, Walk Mill Pit, Moresby; above the Main Band, William Pit, Whitehaven.

CALAMOCLADUS.

CALAMOCLADUS EQUISETIFORMIS (Schl.). (See p. 6.)

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 906 & 908.
Locality.—Above the Main Band, Walk Mill Pit, Moresby.

PINNULARIA, Lindley & Hutton, 1833–35.

'Fossil Flora' vol. ii, p. 81.

PINNULARIA sp.

Woodwardian Mus. Camb., Carb. Plant Coll. No. 924.
Locality.—Above the Cannel Band, Robin Hood Pit, Flimby.

Sphenophyllales.

SPHENOPHYLLUM.

SPHENOPHYLLUM CUNEIFOLIUM (Sternb.) (See p. 7.)

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 913, 914, & 918.
Locality.—Above the Cannel Band, Robin Hood Pit, Flimby.

Lycopodiales.

LEPIDODENDRON.

1. LEPIDODENDRON WORTHENI, Lesq. (Pl. II, fig. 6.)

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 926, 949, & 951.
Locality.—Above the Cannel Band, Robin Hood Pit, Flimby.

Lepidodendron Wortheni.
1866. Lesquereux, 'Geol. Surv. Illinois' vol. ii, p. 452 & pl. xliv, figs. 4–5.
1880. Lesquereux, 'Coal-Flora of the Carbon. in Pennsylvania, &c.' 2nd Geol. Surv. Penn. Report of Progr. P, vol. ii, p. 388 & pl. lxiv, figs. 8–9.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 467 & pl. lxxi, figs. 1–3.
1901. Kidston, Trans. Nat. Hist. Soc. Glasgow, n. s. vol. vi, p. 46, fig. 6.

2. LEPIDODENDRON LYCOPODIOIDES, Sternb. (Pl. II, fig. 5.)

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 927 & 950–51.
Locality.—Above the Cannel Band, Robin Hood Pit, Flimby.

Lepidodendron elegans.
1837. Brongniart, 'Hist. des Végét. foss.' vol. ii, p. 35 & pl. xiv.
1831–37. Lindley & Hutton, 'Foss. Flora' vol. ii, pl. cxviii.
Lepidodendron lycopodioides.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 464, pl. lxix, figs. 2–3 & pl. lxx, fig. 1.
1893. Kidston, Geol. Trans. Yorks. Nat. Union, 'The Yorkshire Carboniferous Flora' 4th Rep. p. 109.

Sigillaria.

Sigillaria lævigata, Brongt. (See p. 8.)

Woodwardian Mus. Camb., Carb. Plant Coll. No. 912.
Locality.—Above the Cannel Band, Robin Hood Pit, Flimby.

Bothrodendron, Lindley & Hutton, 1833.

'Fossil Flora' vol. ii, p. 1.

Bothrodendron minutifolium (Boulay)?

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 917 & 919.
Locality.—Above the Cannel Band, Robin Hood Pit, Flimby.

Rhytidodendron minutifolium.
1876. Boulay, 'Terr. houill. du Nord de la France' p. 39, pl. iii, figs. 1 & 1 bis.
Bothrodendron minutifolium.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 491 & pl. lxxiv, figs. 2–4.
1889. Kidston, Ann. & Mag. Nat. Hist. ser. 6, vol. iv, p. 64, pl. iv & figs. 5–6.
1899. Potonié, 'Lehrb. d. Pflanzenpal.' p. 242, fig. 227.
1901. Kidston, Trans. Nat. Hist. Soc. Glasgow, n. s. vol. vi, pp. 34 & 85, figs. 14–15.

Stigmaria.

Stigmaria ficoides (Sternb.). (See p. 9.)

Woodwardian Mus. Camb., Carb. Plant Coll. No. 903.
Locality.—Above the Main Band, Walk Mill Pit, Moresby.

Filicales.

Zeilleria, Kidston, 1884.

Quart. Journ. Geol. Soc. vol. xl, p. 590.

Zeilleria delicatula (Sternb.). (Pl. II, figs. 1 & 2.)

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 920–21.
Locality.—Above the Cannel Band, Robin Hood Pit, Flimby.

Zeilleria delicatula.
1884. Kidston, Quart. Journ. Geol. Soc. vol. xl, p. 592 & pl. xxv.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 66.
1899. Potonié, 'Lehrb. d. Pflanzenpal.' p. 103, fig. 90 (iii).

Sphenopteris.

1. Sphenopteris obtusiloba, Brongt. (See p. 9.) (Pl. II, fig. 3 *b*.)

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 916 & 922.
Locality.—Above the Cannel Band, Robin Hood Pit, Flimby.

2. Sphenopteris furcata, Brongt. (Pl. II, fig. 3 *a*.)

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 916 & 922.
Locality.—Above the Cannel Band, Robin Hood Pit, Flimby.

Sphenopteris furcata.
1828. Brongniart, 'Hist. des Végét. foss.' p. 179 & pl. xlix, figs. 4–5.
1831–37. Lindley & Hutton, 'Foss. Flora' vol. iii, pl. clxxxi.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 80.
1901. Kidston, Proc. Yorks. Geol. & Polytechn. Soc. n. s. vol. xiv, pl. xxvii, fig. 2.

Palmatopteris furcata.
1899. Potonié, 'Lehrb. d. Pflanzenpal.' p. 120, fig. 106.
1900. Zeiller, 'Élém. de Paléobot.' pp. 85–86, fig. 57.
Diplothmema furcatum.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 147, pl. iv, figs. 5–6 & pl. v, fig. 4.

Mariopteris, Zeiller, 1879.

Bull. Soc. géol. France, ser. 3, vol. vii, p. 92.

1. Mariopteris muricata (Schl.).

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 907, 908, 917, 919 & 921.
Localities.—Above the Cannel Band, Robin Hood Pit, Flimby; above the Main Band, Walk Mill Pit, Moresby.

Mariopteris muricata.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 109.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 173 & pls. xx–xxiii.
1899. Zeiller, Mém. Soc. géol. France, Paléont. Mém. No. 21, vol. viii, p. 32 & pl. ii, figs. 14–15.
1899. Potonié, 'Lehrb. d. Pflanzenpal.' p. 140, fig. 135.
1900. Zeiller, 'Élém. de Paléobot.' p. 94, fig. 67.
Diplothmema muricatum.
1885. Stur, Abhandl. k.k. Geol. Reichsanst. vol. xi, pt. i, p. 393 & pls. xxi–xxiii.
Pecopteris laciniata.
1831–37. Lindley & Hutton, 'Foss. Flora' vol. ii, pl. cxxii.
Pecopteris muricata.
1828. Brongniart, 'Hist. des Végét. foss.' p. 352, pl. xcv, figs. 3–4 & pl. xcvii.

2. Mariopteris latifolia (Brongt.).

Woodwardian Mus. Camb., Carb. Plant Coll. No. 904.
Locality.—Above the Main Band, Walk Mill Pit, Moresby.

Mariopteris latifolia.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 112.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 161, pl. xvii, figs. 1–2 & pl. xviii, fig. 1.
Diplothmema latifolium.
1885. Stur, Abhandl. k.k. Geol. Reichsanst. vol. xi, pt. i, p. 361 & pl. xxvi, figs. 1–2.
Sphenopteris latifolia.
1828. Brongniart, 'Hist. des Végét. foss.' p. 205 & pl. lvii, figs. 1–5.

3. Mariopteris sp. (Pl. II, fig. 4.)

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 917–19.
Locality.—Above the Cannel Band, Robin Hood Pit, Flimby.

These specimens are interesting, as the preservation is unusual. The pinnules have the appearance of being thick, and somewhat reflexed at the edges. The nervation is not at all clear; but I have referred them to this genus on the general habit of the plant.

Neuropteris.

1. Neuropteris heterophylla, Brongt.

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 955 & 961–63.
Localities.—Above the Main Band, William Pit, Whitehaven; above the Cannel Band, Robin Hood Pit, Flimby.

Neuropteris heterophylla.
1828. Brongniart, 'Hist. des Végét. foss.' p. 243, pl. lxxi & pl. lxxii, fig. 2.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 85.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 261, pl. xliii, figs. 1–2 & pl. xliv, fig. 1.

2. Neuropteris tenuifolia (Schl.). (See p. 9.)

Woodwardian Mus. Camb., Carb. Plant Coll. No. 947.
Locality.—Above the Main Band, Walk Mill Pit, Moresby.

3. Neuropteris gigantea, Sternb.

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 938, 948, & 952.
Locality.—Above the Main Band, Walk Mill Pit, Moresby.

Neuropteris gigantea.
1828. Brongniart, 'Hist. des Végét. foss.' p. 240 & pl. lxix.
1886. Kidston, 'Catal. Palæoz. Plants Brit. Mus.' p. 92.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 258 & pl. xlii, fig. 1.
1899. Potonié, 'Lehrb. d. Pflanzenpal.' p. 151, figs. 101, 105, & 150.
1899. Zeiller, Mém. Soc. géol. France, Paléont. Mém. No. 21, vol. viii, p. 44 & pl. iv, fig. 10.
1900. Zeiller, 'Élém. de Paléobot.' p. 105, fig. 79.
1901. Kidston, Proc. Yorks. Geol. & Polytechn. Soc. n. s. vol. xiv, p. 193, pl. xxviii, fig. 3 & pl. xxix, fig. 4.

Alethopteris.

Alethopteris decurrens (Art.).

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 902, 915, & 925.
Localities.—Above the Cannel Band, Robin Hood Pit, Flimby; above the Main Band, Walk Mill Pit, Moresby.

Pecopteris Mantelli.
1828. Brongniart, 'Hist. des Végét. foss.' p. 278 & pl. lxxxiii, figs. 3–4.
1831–37. Lindley & Hutton, 'Fossil Flora' vol. ii, pl. cxlv.
Alethopteris decurrens.
1886–88. Zeiller, 'Bassin houill. de Valenciennes' p. 221, pl. xxxiv, figs. 2–3, pl. xxxv, fig. 1, & pl. xxxvi, figs. 3–4.
1899. Potonié, 'Lehrb. d. Pflanzenpal.' p. 146, fig. 141.

Cordaitales.

Cordaites.

Cordaites principalis (Germar). (See p. 10.)

Woodwardian Mus. Camb., Carb. Plant Coll. Nos. 906, 909, 910, & 915.
Localities.—Above the Cannel Band, Robin Hood Pit, Flimby; above the Main Band, Walk Mill Pit, Moresby.

III. The Palæobotanical Evidence as to the Age of the Beds in the Whitehaven-Maryport District of the Cumberland Coalfield.

A. The Sandstone Series.

It is well known that the age of the lower division of the Sandstone Series was for many years regarded as Permian. Sedgwick,[1] who was probably the first to undertake a systematic study of the Cumberland Coalfield, concluded

'that in . . . these regions the Lower Red Sandstone represents the *rothe todte liegende*, or lowest division of the red sandstone series.'

Previous to Sedgwick's conclusions, this series had been universally regarded as a member of the true Coal-Measures.[2] Sedgwick's views were maintained as late as 1859 by Matthias Dunn.[3] The late

[1] A. Sedgwick (32) p. 345 & (36).
[2] *Id.* (36) p. 395.
[3] M. Dunn (60) p. 141.

E. W. Binney[1] was apparently the first to suspect the correctness of this conclusion, and the rocks in question have been for many years almost universally regarded as Upper Carboniferous in age. As such they appear on the two editions of the Geological Survey Map[2] of the Whitehaven district, published in 1892 and 1895.

The exact horizon of the Sandstone Series in the Carboniferous, as also the position of the Productive Measures, are still disputed questions. The most recently-published theory on the subject is that both these series are probably older than the true Coal-Measures.[3]

Prof. Hull[4] in his 'Coalfields of Great Britain' did not definitely assign the Sandstone Series to any particular horizon in the Coal-Measures.[5] He classified the Upper Carboniferous formations as follows:—

'Coal-measures 2,000 feet.	1. (?) Massive reddish sandstone of Whitehaven. Professor Sedgwick appears doubtful of the affinities of this rock—100 to 150 feet.
	2. *Middle*, most fully developed at Cleat Moor, containing 7 workable coal-seams.
	3. *The Lower*, with 4 or 5 thin and inferior coal-seams.'

Mr. J. D. Kendall[6] has concluded that the whole of the Sandstone Series is of Upper Coal-Measure age. Mr. T. V. Holmes[7] in 1896 stated that

'the only evidence we have about the position among the Coal-Measures of the Whitehaven Sandstone is that furnished by the Frizington-Hall boring.'

It would therefore seem that any fresh light, which a study of the fossil plant-remains may tend to throw on the vexed subject of the age of these beds, would be welcome.

In the first place, the plants obtained from the Sandstone Series confirm, in a most emphatic manner, the conclusions as to the Carboniferous age of the Sandstone Series. The discovery of the *Spirorbis*-Limestone, at a higher horizon in the Sandstone Series than that from which the plants were obtained, renders further proof unnecessary.

The examination of the boring in the Sandstone Series at Frizington Hall by the late Mr. Brockbank[8] in 1891, showed that

[1] E. W. Binney (55) p. 209.

[2] Geol. Surv. Engl. & Wales, 1-inch map, Quarter-sheet 101 S.W., 1892 & 1895.

[3] J. G. Goodchild (n. d.) pp. 20, 27–30.

[4] [My attention has been called, since the reading of this paper, to a footnote (p. 215) in the 3rd edition of 'The Coalfields of Great Britain,' where Prof. Hull states that 'after a personal inspection of this sandstone, I feel no doubt of its belonging to the Coal-Measures.' The same note, and a classification of formations identical with that in the 3rd edition above-quoted, occurs also in the 4th (latest) edition (1881) p. 227.—E. A. N. A., *Dec. 9th, 1902.*]

[5] E. Hull (73) p. 215.

[6] J. D. Kendall (83) p. 322, (95) p. 235, & (96) p. 204.

[7] T. V. Holmes (96) p. 413.

[8] W. Brockbank (91) p. 424.

the Series may probably be divided into two divisions; but the discovery of *Spirorbis*-Limestone did not, as will be shown here, fix the horizon of the Upper Division beyond doubt. As the boring in question must be referred to in some detail, it may be well to give a condensed account of its principal features, taken from the table in Mr. Brockbank's paper.[1]

	Thickness.		Depth below surface.	
	Feet	inches.	Feet	inches.
3. Permian Breccia	20	0	42	0
2. Red and purple sandstones, shales, and conglomerates, with two thin bands of *Spirorbis*-Limestone, and three thin bands of coal	418	8	460	8
1. Red and purple sandstones, shales, and conglomerates	112	7	573	3
Boring ended.				

The occurrence of 20 feet of Permian Breccia, above the *Spirorbis*-Limestone, shows that in all probability the whole of the upper part of the Sandstone Series is present here. Mr. Brockbank was of opinion that, at a depth of roughly 420 feet below the Permian, or 214 feet below the lower band of *Spirorbis*-Limestone, the sandstones presented a similar appearance to those at Whitehaven. If the lower 112 feet is thus correctly identified, then he says[2] 'they thus become Middle Coal-Measure sandstones beyond doubt.' There is no evidence that, even at 573 feet, when the boring ended, the basal beds of the Sandstone Series had been reached. Indeed, if we remember that this series in Bransty Cliff, near Whitehaven, is at least 170 feet thick,[3] and has there been largely denuded, it is probable that the bore only passed through a portion of the full extent of the Lower Division of the Sandstone Series.

(1) Upper Division, Sandstone Series.

The only palæontological evidence, as to the horizon of the Upper Division of the Sandstone Series, is the occurrence of the two bands of *Spirorbis*-Limestone. The value of *Spirorbis*, as marking a particular zone in the Coal-Measures, is, however, becoming smaller every year, in view of the wide vertical range which this fossil has been proved to possess in certain districts. This is particularly the case in the Upper Carboniferous rocks of North Staffordshire, as Mr. Walcot Gibson[4] has recently shown. Mr. Kidston tells me that he has also found that the occurrence of *Spirorbis* does not agree with the evidence of fossil plants in other districts. If, therefore, the occurrence of *Spirorbis* at Frizington Hall can be regarded as of any value at all, it probably points to the Upper Division of the Sandstone Series as belonging to the Transition Coal-Measures, an horizon

[1] W. Brockbank (91) p. 418.
[2] *Ibid.* p. 420.
[3] J. D. Kendall (96) p. 202.
[4] W. Gibson (01) p. 253.

established by Mr. Kidston [1] as intermediate between the Upper and Middle Coal-Measures, and of which the best-known examples are the Lower Pennant Rocks in the South Wales Coalfield, and the New Rock and Vobster Series in the Somerset Coalfield. Trasition Coal-Measures occur also in the Potteries Coalfield of North Staffordshire.

(2) Lower Division, Sandstone Series.

The fossil flora of the Lower Division of the Sandstone Series is undoubtedly of Middle Coal-Measure age. This confirms the late Mr. Brockbank's conclusions.

List of Plant-remains from the Lower Division of the 'Sandstone Series.'

Calamites (Calamitina) approximatus, Brongt.	*Lepidophloios (Halonia)* sp.
Calamites (Calamitina) varians, Sternb.	*Lepidophyllum* sp.
Calamites (Stylocalamites) Suckowi, Brongt.	*Sigillaria scutellata*, Brongt.
Calamites (Stylocalamites) Cisti, Brongt.	*Sigillaria ovata*, Sauveur.
Calamocladus equisetiformis (Schl.).	*Sigillaria lævigata*, Brongt.
Annularia sphenophylloides (Zenker).	*Stigmaria ficoides* (Sternb.).
Sphenophyllum cuneifolium (Sternb.).	*Sphenopteris obtusiloba*, Brongt.
Lepidodendron aculeatum, Sternb.	*Neuropteris tenuifolia* (Schl.).
	Neuropteris Scheuchzeri, Hoffm.
	Alethopteris Serli (Brongt.).
	Cordaites principalis (Germ.).
	Cordaites sp.

The aggregate or assemblage of fossil-types, and the abundance of certain groups or genera, as shown here, all point to Middle, and not to Upper Coal-Measures, as the age of these beds. The common occurrence of *Calamites* and *Lepidodendra*, in association with *Sigillaria* and *Cordaites*, favours this conclusion.

There is also an entire absence of those types of fern-like plants that are associated essentially with the Upper Coal-Measures. It is true that some of these plants, such as *Calamites approximatus*, *Lepidodendron aculeatum*, and *Sigillaria scutellata*, extend to the Transition, or even to the Upper Coal-Measures, but these species are all much more characteristic of the Middle and Lower Coal-Measures than of the Upper Series.[2] Finally, the occurrence of *Sigillaria ovata*, a plant confined to the Middle Coal-Measures, confirms this conclusion.

In a paper, which is concerned entirely with palæobotanical evidence, it is not possible, at present, to offer any opinion on the disputed question of the correlation of rocks, of somewhat similar petrological structure, in other districts with the Sandstone Series of Cumberland. Mr. Holmes [3] has repeatedly put forward the view that the Red Rock of Rotherham in Yorkshire is the equivalent of the Whitehaven Sandstone. No plants have been described from

[1] R. Kidston (94) pp. 228–29, and (97) p. 129. Mr. Kidston tells me that he proposes to speak of this horizon in future as the Upper Transition Coal-Measures.

[2] R. Kidston (94) pp. 228 & 233.

[3] T. V. Holmes (83) p. 409 & (96) p. 407.

these Yorkshire beds, so far as I am aware; and I have been unable, after many enquiries, to ascertain the existence of such remains in any museum, with the exception of two specimens in the Woodwardian Museum at Cambridge.[1] Until such specimens have been obtained (and there would seem to be no reason to doubt the existence of a fossil flora), there is no evidence of a palæobotanical character on this point.

B. The Productive Measures.

Sedgwick[2] divided these Measures into an upper portion, including the Main and Bannock Bands, and a lower, represented by four or five workable but inferior coals. The opinions of Prof. Hull and others, as to the horizons represented by these beds, have already been quoted.

(1) Upper Division, Productive Measures.

The following plant-remains were obtained from the horizon of the Main Band in various localities in the Cumberland Coalfield:—

List of Plant-remains from the Upper Division of the 'Productive Measures.'

**Calamites (Calamitina) varians*, Sternb.
**Calamites (Stylocalamites) Suckowi*, Brongt.
**Calamites (Stylocalamites) Cisti*, Brongt. ?
**Calamocladus equisetiformis* (Schl.).
Pinnularia sp.
**Sphenophyllum cuneifolium* (Sternb.).
Lepidodendron Wortheni, Lesq.
Lepidodendron lycopodioides, Sternb.
**Sigillaria lævigata*, Brongt.
Bothrodendron minutifolium (Boulay)?
**Stigmaria ficoides* (Sternb.).
Zeilleria delicatula (Sternb.).
**Sphenopteris obtusiloba*, Brongt.
Sphenopteris furcata, Brongt.
Mariopteris muricata (Schl.).
Mariopteris latifolia (Brongt.).
Mariopteris sp.
Neuropteris heterophylla, Brongt.
**Neuropteris tenuifolia* (Schl.).
Neuropteris gigantea, Sternb.
Alethopteris decurrens (Art.).
**Cordaites principalis* (Germar).

The conclusion drawn from this flora is that the horizon of the Main Band is undoubtedly of Middle Coal-Measure age. The remarks made in regard to the flora of the Lower Division of the Sandstone Series apply equally here; and the occurrence of *Zeilleria delicatula*, a plant confined to the Middle Coal-Measures, places the matter beyond doubt, so far as our present knowledge of the distribution of fossil-plants is concerned. The flora is also largely identical with that above mentioned, nearly half the species being common to the two. In the foregoing list, those species marked with an asterisk (*) are represented in both floras. Finally, the occurrence of such plants as *Lepidodendron Wortheni*, *Sigillaria lævigata*, and *Neuropteris tenuifolia* at once serves to distinguish this from a Lower Coal-Measure flora.

With, I think, only one exception, all the plants mentioned here

[1] These are a fine specimen of *Sigillaria tessellata* (Schl.) and a leaf of *Alethopteris lonchitica* (Schl.), both recorded from Rotherham, but without horizon.
[2] A. Sedgwick (36) p. 393.

from the Sandstone Series, and also from the Productive Measures, have been recorded from the Middle Coal-Measures of Yorkshire,[1] and the great majority also from the Middle Coal-Measures of Lancashire.[2]

I am happy to be able to state that Mr. Kidston, to whom I have shown the evidence presented here, entirely agrees with me as to the age of both these floras.

(2) Lower Division, Productive Measures.

With regard to the age of horizons in the Productive Measures, below the Main Band, nothing definite is known at present. No fossils of any sort have been described from these beds, and attempts to obtain plant-remains have not been successful. The full extent of the Middle Coal-Measures, as also the existence, or non-existence of Lower Coal-Measures, has yet to be demonstrated.

Among the many geological problems awaiting solution in this district, the identification of the base of the Productive Measures, the Millstone Grit, is one of the most important. After careful enquiries, I find that this rock has never been identified in any section beneath the Main Band at any colliery, or boring, in this district of the Cumberland Coalfield. Yet in the Geological Survey 1-inch Map,[3] rocks, described as Millstone Grit, are shown to crop out some 4 or 5 miles inland from the coast, from Whitehaven to Workington. The base of the Productive Measures is therefore at present undefined. In two localities at least:—at Harrington, and recently in the Ladysmith Shaft of the Croft Pit, Whitehaven, a limestone, presumably to be regarded as Carboniferous Limestone, has been reached below the coals. In the latter case [4] the limestone was first reached at 327 feet below the Main Band, and between these two horizons, arenaceous and argillaceous rocks occurred in nearly equal proportions, and also several coal-seams. The boring ended at a depth of 89 feet beyond the first limestone, passing through sandstones, shales, and several other limestone-bands. The above record may serve as an illustration of the uncertainty, which at present prevails, as to the base and extent of the Productive Measures.

IV. Conclusions.

The chief conclusions, based on the discovery of fossil floras in the Lower Division of the Sandstone Series, and in the Upper Division of the Productive Measures, are that both these divisions are of Middle Coal-Measure age. Consequently the change in lithological conditions, which resulted in the deposition of the Sandstone Series above the Productive Measures, took place in Middle Coal-Measure times. Also, since there was a considerable accumulation of both types of deposit during that period, the

[1] R. Kidston (90). [2] *Id.* (92).

[3] Quarter-sheet 101 S.W. 1895.

[4] From particulars kindly supplied by Mr. James, Secretary of the Whitehaven Colliery Company.

unconformity, if present, between the two, does not mark any considerable interval in geological time, during which there was a cessation of deposition, and a period of erosion. The following table summarizes the main conclusions arrived at:—

The Age of the Upper Carboniferous Beds of Cumberland, based on Palæontological Evidence.

System.	*Series.*	*Stage.*	*Thickness in feet.*	*Petrological Character.*	*Palæontological Evidence.*	*Horizon.*
PERMIAN.	Brockram.		20	Red breccia.		Lr. Permian.
UPPER CARBONIFEROUS.	Sandstone Series (Whitehaven Sandstone in part). 600 feet at least.	Upper Division.	418	Red & purple sandstone.	*Spirorbis*-Limestone (Brockbank 1891).	? Transition Coal-Measures.
		Lower Division.	200 at least.	Red or grey sandstone.	Middle Coal-Measure flora.	Middle Coal-Measures.
	Productive Measures. ? 1300 feet.	Upper Division, including Bannock and Main Bands.	450 at least [William Pit, Whitehaven].	Dark-coloured shales and coal.	Middle Coal-Measure flora.	
		(?) Lower Division.	(?)	(?)	—	? Lower Coal-Measures, and Millstone Grit.

In conclusion, I wish to express my great indebtedness to Mr. P. L. Addison, F.G.S., of Bigrigg, for the kindness with which he obtained for me every facility for the collection of specimens in the field, and for special help in many directions. I am also under obligations to Mr. Robert Kidston, F.R.S., who has most kindly given me the benefit of his opinion on special points of identification. I should also like to take this opportunity of expressing my thanks to many Fellows of the Geological Society, who have kindly answered enquiries, and given me information concerning the Cumberland District.

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EXPLANATION OF PLATES I & II.

All the specimens are in the Woodwardian Museum, Cambridge.

[The figures are reproduced from photographs taken by Mr. Tams, Cambridge. They are all approximately of the natural size, except Pl. II, fig. 2.]

PLATE I.

Fossil Plants from the Sandstone Series.

Figs. 1 & 2 from specimens in the John Woodward collection, formed before 1729 A.D.; figs. 3–5 from specimens collected by Adam Sedgwick.

Fig. 1. *Neuropteris Scheuchzeri*, Hoffm.
2. *Neuropteris obliqua* (Brongt.).
3. *Calamites* (*Calamitina*) *approximatus*, Brongt.
4. *Lepidodendron aculeatum*, Sternb.
5. *Sigillaria scutellata*, Brongt.

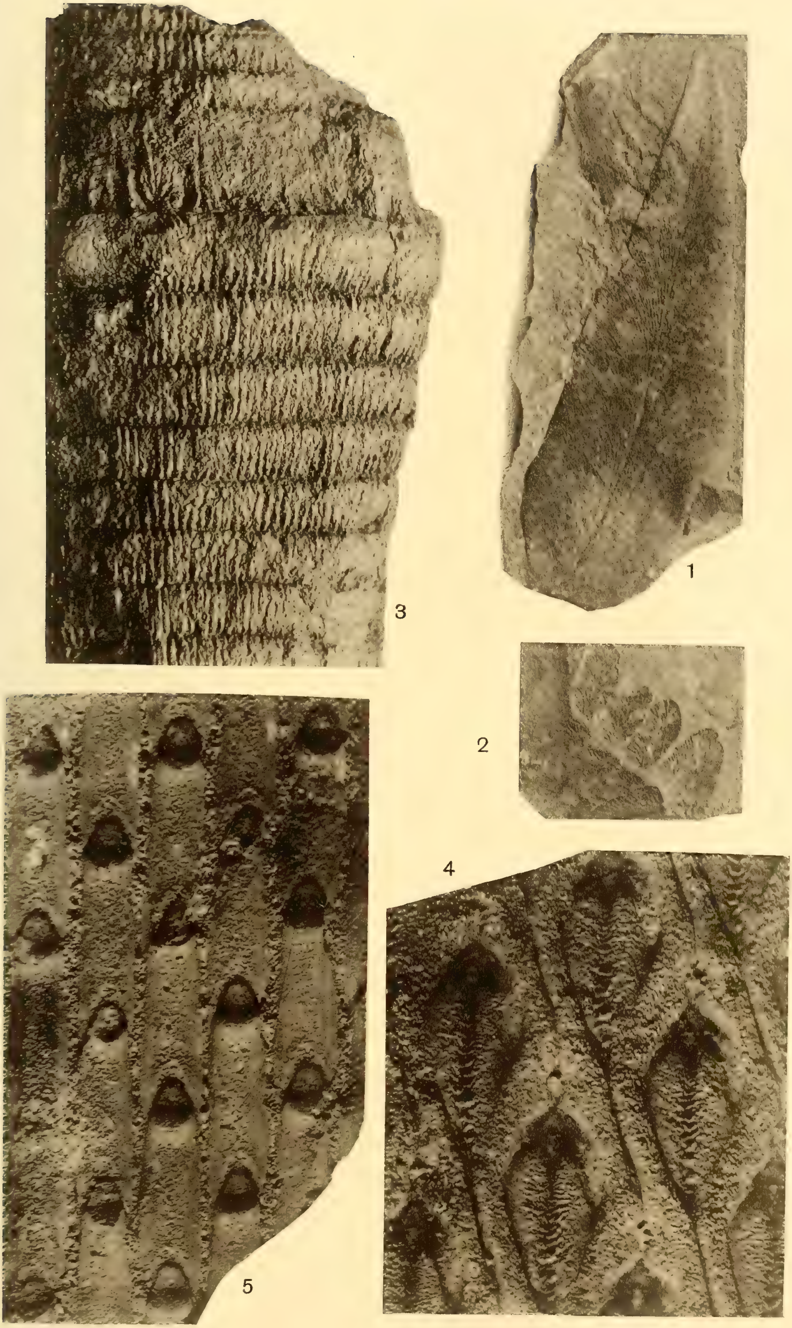
PLATE II.

Fossil Plants from the Productive Measures.

Specimens collected by the Author.

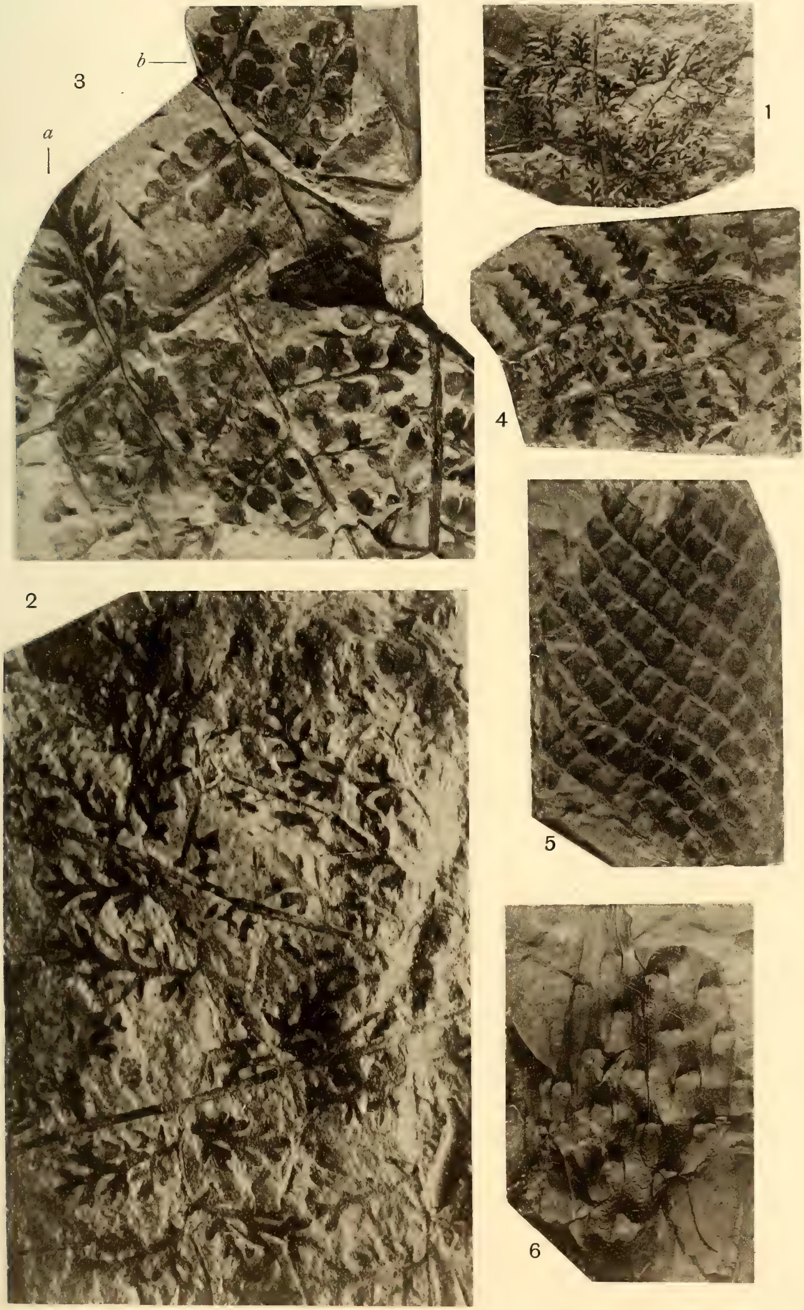
(These photographs need to be examined with a hand-lens.)

Fig. 1. *Zeilleria delicatula* (Sternb.).
2. Do. do. ×4.
3. { a. *Sphenopteris furcata*, Brongt.
   b. *Sphenopteris obtusiloba*, Brongt.
4. *Mariopteris* sp.
5. *Lepidodendron lycopodioides*, Sternb.
6. *Lepidodendron Wortheni*, Lesq.



Tams, Photo. *Bemrose Ltd., Collo.*

Fossil Plants from the Cumberland Coalfield.



Tams, Photo. *Bemrose Ltd., Collo.*

FOSSIL PLANTS FROM THE CUMBERLAND COALFIELD.

Discussion.

The President pointed out that, although the Carboniferous was the thickest system in Britain, and had been longest studied, geologists were still very far from having arrived at any universally applicable means of establishing the detailed chronological parallelism of the members of the sequences developed in the separate Carboniferous areas. From the lithological point of view, the groupings associated with the work and publications of Prof. Hull were perhaps of the best available working value. But from the strictly chronological point of view, the only definite conclusion that appeared yet to be regarded as satisfactorily established was that the Carboniferous as a whole was separable into a Lower and Upper division at the base of the Millstone Grit, a result especially due to the researches of Dr. Traquair among the Carboniferous fishes. Of the possible zonal divisions of the Lower Carboniferous, little or nothing was as yet known. But the endeavour to separate the Upper Carboniferous into chronological divisions by means of their characteristic plants —with which were associated especially the names of Stur on the Continent and Kidston in Britain—had now reached a stage which gave every promise of success. It was pleasant to learn that the Author of the paper found that the Upper Carboniferous plants studied by him in the Whitehaven Coalfield had not only a vertical distribution corresponding to that ascertained elsewhere, but they were of value here also as aids in the stratigraphical correlation of their containing beds. He did not gather from the Author's remarks whether the so-called 'Millstone Grit' of the Whitehaven Coalfield could be definitely accepted as such. He believed that the suggested parallelism of the Whitehaven Sandstone with the Lower Pennant Grit of South Wales was not only novel, but an advance of interest and importance.

The Secretary, by permission of the President, read the following extracts from a letter received from Dr. Wheelton Hind :—

'I don't at all know what conclusions Mr. Newell Arber may have arrived at as to the age of the Cumberland Coalfield, but just recently I have been examining a series of lamellibranchs, collected by Miss J. Donald, from the All Hallows coal-pit, which is some little way from Aspatria, in the northern part of the Cumberland Coalfield, and I found *Carbonicola acuta*, *C. aquilina*, and *Anthracomya Williamsoni* among them. The latter is important, as regards its position both in South Wales and the North Staffordshire Coalfield, and points to seams low down in the series. The only bed in which it occurs in North Staffordshire is the Hard-Mine coal, which is generally included in the Lower Coal-Measures; but that subdivision is in North Staffordshire a very arbitrary one, and I should prefer to make the division between Middle and Lower, just below this Hard-Mine seam. The division is as unnecessary as it is arbitrary. I have never in any coalfield found *A. Williamsoni* much off the same line, and consider it a good and reliable index of position. The other two lamellibranchs obtained at All Hallows are found at, above, and below the horizon of *A. Williamsoni*.'

Prof. Hull concurred with the President's statement that the paper was of great interest and value. The list of fossil plants produced by the Author clearly established the Upper Carboniferous age of the Whitehaven Sandstone. He questioned, however, very much whether it could be regarded as the representative of the Pennant Grit of South Wales and Somerset, which he regarded

as due to a local and abnormal development of siliceous rock near the centre of the Coal-Measures of the South of England and Wales. On the other hand, he thought it not improbable that the Whitehaven Sandstone had its representative in the Upper Red-Sandstone Series of Lanarkshire and the Clyde Basin, which was well developed at Hamilton.

Dr. Traquair said that he had listened to the paper with very great interest, but regretted that he was not personally acquainted with the district, nor had he seen any fish-remains from the coal-bearing beds in question. With regard to the stratigraphical value of fishes in the Carboniferous system, he stated that the estuarine fish-fauna of the Lower Carboniferous strata was characterized by a different assemblage of forms from that of the Upper, very few species passing the boundary of the base of the Millstone Grit. As regards the Upper Carboniferous division, almost all the species common in the Lower Coal-Measures reappeared in the Middle, so that the fishes could not be, in the present state of our knowledge, depended on for differentiation between these two horizons. He had seen no fish-remains from the true Upper Coal-Measures of England.

Dr. D. H. Scott congratulated the Author on his paper, and on the beauty of his photographs of the fossil plants described. He thought that on palæobotanical evidence the Author had made out a strong case for a Middle Coal-Measure horizon.

The Author, in reply to the President, said that he did not mean in any way to suggest that the Millstone Grit was absent from the Cumberland Coalfield. Such rocks are marked on the Geological Survey Map (101 S.W.), a few miles inland from the coast, extending from the neighbourhood of Whitehaven to Workington. His observations were intended to call attention to the fact that the Millstone Grit had never been identified in any boring below any of the great coal-seams of the district, and consequently the vertical extent of the Productive Measures was still uncertain.

In reply to Prof. Hull, the Author said that the upper division of the Sandstone Series was doubtless not the exact equivalent of the Lower Pennant Grit of South Wales. The somewhat scanty evidence, at present available, merely suggested that the Upper Sandstone Series may eventually prove to occupy about the same horizon in the Coal-Measures.

The communication forwarded by Dr. Wheelton Hind with regard to the discovery of lamellibranchs by Miss Donald at All Hallows, referred to the Aspatria district of the Cumberland Coalfield, where the age and succession of the beds were also in dispute, and this discovery would probably throw some light on these questions.

2. REMARKS *upon* Mr. E. A. NEWELL ARBER'S *Communication: On the* CLARKE COLLECTION *of* FOSSIL PLANTS *from* NEW SOUTH WALES. By Dr. F. KURTZ, Professor of Botany in the University of Córdoba, Argentine Republic. (Communicated by A. C. SEWARD, Esq., M.A., F.R.S., F.L.S., F.G.S. Read November 5th, 1902.)

THE perusal of Mr. Arber's above-cited paper[1] has suggested to me the following observations.

I quite agree with Mr. Arber's identification of the specimens figured in his pl. i, figs. 1 & 2, with *Rhiptozamites Gœpperti*, Schmalh., which I take to be a synonym of *Nœggerathiopsis Hislopi* (Bunb.) Feistm., as I already stated in 1894 (1).[2] *Podozamites elongatus* (Morr.), Feistm., however, I regard as quite different from *Nœggerathiopsis Hislopi*. In the first place, we have Morris's specimens from the Jerusalem Beds, Tasmania (which I know only from Feistmantel's figures): these represent an oblong-lanceolate, nearly ribbon-shaped leaf, tapering towards the base, where it is constricted in quite a Cycadean fashion—a feature never observed in our very numerous specimens of *Nœggerathiopsis*—and traversed by a rather restricted number of basally bifurcating nerves (about ten nerves are to be seen at the base, and eighteen to twenty-two in the middle of the leaflets), which occur as parallel and not as spreading veins, and unite a short distance below the apex. With this plant (*Zeugophyllites elongatus*, Morris), Szajnocha (2) identified a fossil from Cacheuta, Mendoza; and Feistmantel (3) afterwards instituted *Podozamites elongatus* (from Cape specimens), a fact overlooked by Mr. R. Etheridge, Jun. (4), as well as by Mr. Arber. Mr. Etheridge distinguished very well the Mulubimba plant, and gave a rather good description of *Nœggerathiopsis Hislopi*, Fstm. We possess quite a series of leaves from Cacheuta, which prove, first, Szajnocha's determination to be correct, and, secondly, that *P. elongatus*, Fstm., is quite a different plant from *Nœggerathiopsis Hislopi*, Fstm. (=*Rhiptozamites Gœpperti*, Schmalh.). There are some leaves of *Nœggerathiopsis*, which present—at least in their upper part—parallel margins like *Podozamites*, but are immediately distinguished from the Cycadean plant by the comparatively much larger number of spreading nerves (the spreading veins also serve in most cases as a distinguishing feature from *Cordaites*), and by their texture, as far as this can be ascertained. The leaves of *Nœggerathiopsis* seem to have been rather delicate, thin, and membranaceous (more or less decayed leaves are infrequently met with), comparable, for instance, with the leaflets of the living *Caryota mitis*, Lour.; while the pinnæ of *Podozamites* appear to present a more leathery texture, like those of our *Zamia media*, Jacq., or *Z. muricata*, W. I cannot therefore see any reason to alter the synonymy of *Nœggerathiopsis*, as

[1] Quart. Journ. Geol. Soc. vol. lviii (1902) p. 1.
[2] Numerals in parentheses refer to the Bibliography on p. 26

I established it in 1894 (*op. cit.*); and I believe that Mr. Arber, with my specimens and drawings in hand, will adopt my view.

My second remark bears upon *Otopteris ovata*, McCoy, which Mr. Arber separates specifically and generically from *Rhacopteris inæquilatera* (Gœpp.) Stur, Fstm., as *Aneimites ovata* (McCoy) N. Arber. Of the single specimen of this plant in the Clarke Collection, Mr. Arber observes, on p. 21 of his paper:—

'The nervation in the Cambridge specimen is finer, more graceful, and less rigid, and at the same time somewhat closer, more radiating, and spreading. The nerves also dichotomize more than once, in some cases as often as four times.'

These remarks apply equally well to the plant—also from Arowa—figured by Feistmantel (5) in his pl. vi, fig. 1 (but less to pl. iv, fig. 3), the veins of which, so far as can be seen, dichotomize as much as three times, and the aspect of which in general is not so rigid as that of the specimens represented in Feistmantel's pls. v, viii, etc. Whether *Aneimites austrina*, Eth. belongs here I cannot say, as we do not possess the publication in which it is figured. There does not appear to be sufficient evidence for separating *Otopteris ovata*, McCoy from *Rhacopteris inæquilatera*, Stur, where it may well be retained, perhaps as a variety—var. *ovata* (McCoy sp.): 'pinnarum nervi tenuiores, repetito (ter quaterve) dichotomi, unde rami eorum excurrentes numerosiores, densioresque.'

As a closing remark I may add that *Rhacopteris inæquilatera*, Stur, has also been found in the Argentine, and was described by Geinitz (6) as *Otopteris argentinica*, Gein.

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(2) L. SZAJNOCHA. 'Ueber fossile Pflanzenreste aus Cacheuta in der Argentinischen Republik' Sitzungsber. d. k. k. Akad. d. Wissensch. Wien, math.-naturw. Cl. vol. xcvii (1888) pp. 219–45 & pls. i–ii.

(3) O. FEISTMANTEL. 'Uebersichtliche Darstellung der geologisch-paläontologischen Verhältnisse Süd-Afrikas: I. Theil.—Die Karoo-Formation und die dieselbe unterlagernden Schichten' Abhandl. d. math.-naturw. Cl. d. k. böhm. Gesellsch. d. Wissensch. Prag, ser. 7, vol. iii (1889), No. 6; 89 pp. & 4 pls.

(4) R. ETHERIDGE, Jun. 'On the Occurrence of a Plant, allied to *Schizoneura*, in the Hawkesbury Sandstone' Rec. Geol. Surv. N. S. W. vol. iii, pt. iii (1893) pp. 74–77 & pl. xiii.

(5) O. FEISTMANTEL. 'Geological & Palæontological Relations of the Coal- and Plant-bearing Beds of Palæozoic & Mesozoic Age in Eastern Australia & Tasmania, with Special Reference to the Fossil Flora' Mem. Geol. Surv. N. S. W. Palæontology, No. 3, 1890.

(6) H. B. GEINITZ. 'Beiträge zur Geologie und Paläontologie der Argentinischen Republik II. Paläontologischer Theil. IIte Abtheilung: Ueber rhätische Pflanzen- und Thierreste in den argentinischen Provinzen La Rioja, San Juan, u. Mendoza' Cassel (1876); 14 pp. & 2 pls.

DISCUSSION.

Mr. E. A. N. ARBER remarked that the first part of the Author's criticism was concerned with the species described in the speaker's paper (p. 17) as *Nœggerathiopsis Gœpperti* (Schmal.). He was

delighted to find that the Author agreed with the chief and most important conclusion at which he had arrived on this subject; in which he was the first to point out that Clarke's plant, wrongly termed by McCoy in 1847 *Zeugophyllites elongatus*, Morris, was identical with the *Rhiptozamites Gœpperti* of Schmalhausen from the Permian of Russia, now known as *Nœggerathiopsis Gœpperti* (Schmal.).

The Author, however, went further, and regarded *Rhiptozamites Gœpperti*, Schm., as identical with the Indian form *Nœggerathiopsis Hislopi* (Bunb.). In this the speaker ventured to disagree with him. The former had clearly shown, in a paragraph in his paper (p. 20) on this subject, that, while acknowledging the great similarity between these two species, he could not satisfy himself as to their identity. In this conclusion he had weighty opinion on his side, in the support of Prof. Zeiller, whose opinion he quoted (p. 20, footnote 2), and of the late Ottokar Feistmantel, Pal. Indica, 'Foss. Flora Gondwana Syst.' vol. iii. (1. Suppl.) p. 56, and (3.) p. 118, who also hesitated to unite them.

The Author further implied here, and also in another portion of his communication, that he was the first to put forward, in 1894, the suggestion that these two species might be identical. But at least one other observer, Kosmovsky, had come to this conclusion in 1891, a fact to which the speaker gave a reference in quoting Prof. Zeiller's paper above mentioned, for this note of Prof. Zeiller was written specially on Kosmovsky's conclusions.

The next part of the Author's criticism arose from the fact that two different Australian plants were described under the same name, first by Morris in 1845, and then by McCoy in 1847, with subsequent confusion in the literature. The most recent names for these were respectively *Podozamites elongatus* (Morris) and *Nœggerathiopsis Gœpperti* (Schmal.). The Author pointed out in some detail that these two plants were different. But this was unnecessary, as the speaker had stated in his paper (p. 19, par. 2) that this was first proved by Mr. Etheridge, Jun., in 1893. The speaker had also shown that he accepted Mr. Etheridge's conclusions, by urging that the specific name '*elongata*' should be retained for Morris's plant, and not for McCoy's: the true nature of the latter being then unknown.

The Author was mistaken in supposing that the speaker was unaware of the identification of the Australian species, first known as *Zeugophyllites elongatus*, by Szajnocha among South American, and by Feistmantel among South African, specimens. The reference to the former would be found in footnote 4 on p. 19 of the speaker's paper, with a special remark on this very subject. No reference was, however, made to Feistmantel, since the speaker was only concerned with Morris's plant as far as it had been confused with McCoy's. To have given a full history of Morris's plant, when there was no specimen of it in the Clarke Collection, would have been inadvisable, and a reference to Szajnocha was given, and then only as a footnote.

The Author then went on to show that Szajnocha's South American specimens were identical with Morris's plant. His reason for this was apparently due to the Author having misunderstood the special note appended by the speaker on that observer's work, as above mentioned. The speaker pointed out in that note that 'Dr. Szajnocha's identification of Argentine specimens with *Zeugophyllites elongatus* is inconclusive' (p. 19, footnote 4). The reason, which he thought would be apparent, was that Szajnocha, writing in 1888, before it was known (1893) that Morris's and McCoy's plants were different, and including both these in his synonymy on p. 237 of his paper, could not have shown (what the Author had no doubt stated correctly in his criticism) that the South American specimens were identical with Morris's plant, rather than McCoy's. The fact that the South American specimens had turned out to be identical with Morris's species, as the Author had clearly shown, was interesting and important, but it did not alter the fact that Szajnocha's determinations in 1888 were inconclusive, as the speaker had stated, since two different plants were then known under one name. We owe it to the Author's communication that this point is now satisfactorily cleared up.

The second part of the Author's criticism referred to a plant from Arowa, which the speaker had named in his paper (p. 21) *Aneimites ovata* (McCoy). The speaker had stated there at some length his reasons for being unable to identify this plant with *Rhacopteris inæquilatera*, Gœpp., specimens of which Feistmantel had obtained from Arowa. That conclusion was one of the most important in the whole paper. Here again there was a simple difference of opinion between the Author, who had never seen the type-specimen, and the speaker. The opinion expressed in the speaker's paper was arrived at conjointly with Mr. Seward who, as he there stated, very kindly gave him the benefit of his opinion on the more critical questions of identification. At that time they had lying before them McCoy's type, typical British specimens of *Rhacopteris inæquilatera*, and Feistmantel's figures of the same plant from various localities in Australia, including Arowa. The conclusion at which they arrived was fully expressed in the speaker's paper. In consequence of the Author's criticism, they had together re-examined the three pieces of evidence above mentioned; and the speaker had Mr. Seward's authority for stating that he entirely agreed with him in regarding McCoy's type as quite distinct from *Rhacopteris inæquilatera*, Gœpp. This conclusion should have weight, as on both occasions they had before their eyes the actual type-specimen of McCoy.

3. *On a* NEW BORING *at* CAYTHORPE (LINCOLNSHIRE). By HENRY PRESTON, Esq., F.G.S. (Read November 5th, 1902.)

DURING the early part of the present year (1902) a boring was made near Caythorpe, for the purpose of obtaining a water-supply from the Marlstone Rock-bed of the Middle Lias. The work was done for Mr. E. Lubbock, of Caythorpe Court, and the boring is about a third of a mile east of the house. A well has been dug to a depth of 46 feet, and from the bottom of this well a 6-inch boring was put down. The thickness of the Upper Lias in this district is usually taken to be about 110 feet, but the present boring has shown it to have here a thickness of 199½ feet. The section is as follows:—

		Thickness. Feet.	*Depth.* Feet.
Surface-deposits	Soil	1	
	Sand and yellow clay	3½	4½
NORTHAMPTON SANDS	Ferruginous limestone	4½	9
UPPER LIAS	Blue clay, with layers of concretionary nodules	199½	208½
MARLSTONE	Dark greenish-blue limestone.	19½	228
MIDDLE LIASSIC CLAYS	Hard silty clay, greenish in colour, sandy and micaceous.	to 3½	231½

The rest-level of the water in the borehole is at a depth of 175 feet from the surface, or 145 feet above Ordnance-datum.

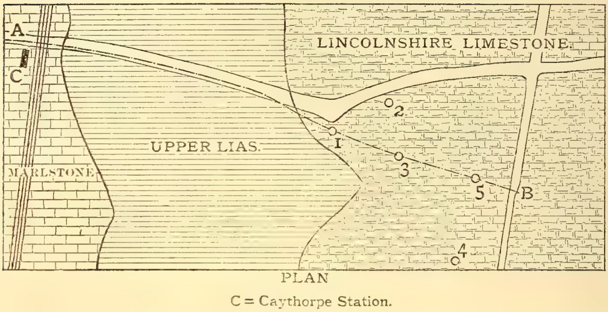
The boring was made by Mr. J. E. Noble, of Thurlby, near Bourne, under my own superintendence, and samples of boring-débris were sent to me at frequent intervals. Previous to this boring being made, four other wells had been sunk, which passed through the limestone and into the Liassic clay. The positions of these wells are shown on the plan (fig. 1, p. 30).

The normal dip of the beds is south-easterly, and, as will be noticed, Wells Nos. 1, 3, & 5 lie approximately in the line of dip, and in continuation of the lower part of the road; and hence a section (fig. 2, p. 30) taken along this road and through Wells Nos. 1, 3, & 5, gives the contour of the Upper Lias. This contour shows that the limestone lies irregularly on the clay, and has a decided dip towards the west, a direction opposite to the normal dip. It would thus appear that the limestone has settled down from some cause, upon the eroded surface of Upper Liassic clay, and has masked the true thickness of this clay.

In searching out the cause of this settling down of the limestone, it must be mentioned that a spring crops out by the roadside, just at the junction of limestone and clay. This is one of the ordinary overflow-springs, somewhat common along the western face of the escarpment; and although the spring is a small one, it has the reputation of continuing to flow for the greater part of the year. The mere fact that it is continuous in its flow would suggest that some alteration of strata has taken place, whereby the area of its gathering-ground is increased; but it is

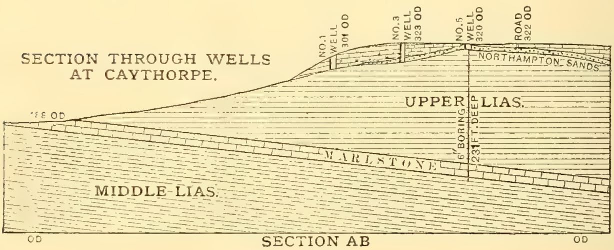
not often that suitable wells are sunk whence the exact formation of the strata can be traced. The above-mentioned section, taken through the wells, seems to reveal the fact that throughout past ages, the outflowing water of the overflow-spring has carried away,

Fig. 1.—*Plan showing sites of wells.*



[Scale: $2\frac{1}{2}$ inches = 1 mile.]

Fig. 2.—*Section along the line A B in fig. 1.*



[Vertical scale: 330 feet = 1 inch.]

Well No. 1 is 16 feet deep; it touched Liassic clay at 16 feet, and its surface level is 301 feet above O.D.

Well No. 2 is 40 feet deep; it touched clay at 30 feet, and its surface-level is 325 feet above O.D.

Well No. 3 is 32 feet deep; it touched clay at 31 feet, and its surface-level is 323 feet above O.D.

Well No. 4 is 32 feet deep; it touched clay at 32 feet, and its surface-level is 320 feet above O.D.

Well No. 5 is the boring above described, and its surface-level is 320 feet above O.D.

not only the Northampton Sands, and perhaps some of the lower beds of limestone, but also much of the upper surface of the clay, and the limestone has gradually settled down on to its new bed. Thus, not only is a greater area of gathering-ground provided for the spring, but at the same time the true thickness of the Liassic clay has been hidden.

Further evidence may be gathered from the following observations:—

(*a*) The waste-heap, representing the uppermost 38 feet of the Upper Lias, contained numerous fossils. *Leda ovum* was abundant, and one specimen had *Discina reflexa* attached to it. *Ammonites bifrons* was also fairly numerous, together with *Myacites donaciformis*, and belemnites, and also a large fragment of *Ammonites heterophyllus*.

(*b*) The fragments of undisturbed clay washed from the samples taken at every few feet of the boring, showed an amorphous condition, until a depth of 190 feet had been reached. From this depth the washed-up fragments had a decidedly laminated appearance, and this was taken to indicate that the paper-shales, which occur at the base of the Upper Lias, had been reached.

(*c*) At one time, when the clay held out to so unexpected a thickness, it was thought probable that the boring-rods had passed through a fissure in the Marlstone, but no samples of clay brought up seemed to indicate this, there being neither mica nor sand to be found in the clay above the Marlstone.

(*d*) The Marlstone-Rock was of the usual dark greenish-blue colour, and one fragment contained a portion of a shell of *Terebratula punctata*.

(*e*) As soon as the Rock-bed had been passed through, the character of the clay changed. It was greenish, and both sandy and micaceous, the sand and mica being in thin layers $\frac{1}{16}$ inch apart. The sand-grains washed from the clay are very small, being from $\frac{1}{500}$ to $\frac{1}{250}$ inch in their longest diameter, with a very few larger grains mixed with them. They consist of sugary quartz, and are all perfectly angular fragments.

(*f*) South of the line of section, there is a slight depression in the ground, which terminates with the easterly projecting tongue of Lias seen in plan. There is also a noticeable depression running for about a mile northward, and passing through the position of Well No. 5. This seems to indicate that the mass of Limestone lying west of this depression has broken its back along this line, and has a tendency to slip westward.

(*g*) Finally, after sinking Well No. 2, which is called the Engine-house Well, a heading was driven for several yards south, it being at the junction of clay and limestone; and I am informed by Mr. Smith, engineer to Mr. Lubbock, that the only flow of water coming into this well and heading is from two small fissures on the east side, showing that the flow of water is with the slipped limestone.

Postscript.

[It seems to be thought possible that a north-and-south fault exists west of Boring No. 5. In relation to this there are two facts which appear to indicate that the continuity of the Marlstone has not been broken by a fault on the west side of the boring:—

(1) The inclination of the roadway west of A (see fig. 1, p. 30)

varies from 82 to 88 feet per mile (6-inch Map, Quarter-sheet No. 96 S.W., Lincolnshire), and this is on the dip-slope of the Marlstone Rock-bed. A mean dip of 82 feet per mile gave the top surface of this rock at Boring No. 5 as 117 feet above Ordnance-datum. The actual datum at which the rock was struck is 111·5 feet O.D., a discrepancy which would hardly allow for a fault.

(2) There is a good flow of water to the borehole; this would not be the case if such a fault had existed.

A downthrow to the east, just beyond the boring, might leave the water-supply intact, but it would not help to explain the thickness of Upper Lias at the boring; and although a reversed fault might explain the unexpected thickness of clay, it would have cut off all water-supply from the Marlstone.

Altogether, then, there does not appear to be anything gained by assuming a north-and-south fault.—H. P., *December 12th, 1902.*]

Discussion.

Prof. W. W. Watts congratulated the Society on listening to an admirable paper containing several important points carefully and tersely stated. Three distinct points had been made out:—the 'creep' of the limestone down the escarpment; the washing-out of the Northampton Sands under the creeping limestone; and the development of an extended drainage-area for the springs in front of the scarp.

Mr. Whitaker remarked that it was a general result of well-sections to increase the known thickness of certain stratigraphical groups. The evidence of 'creep' down the escarpment was important. The phenomenon was more common than geologists generally imagined, and he cited in this connection what is happening to the Lower Greensand-escarpment in part of Surrey, where landslips on a large scale are likely to come about sooner or later. He was glad that the Author was taking care to have all the borings in Lincolnshire recorded, and congratulated him on a most valuable piece of work.

4. *On some* Well-Sections *in* Suffolk. By William Whitaker, B.A., F.R.S., F.G.S. (Read December 3rd, 1902.)

Some 470 well-sections in Suffolk were noticed in thirteen Geological Survey Memoirs up to the year 1893. Many of these were shallow, but many were of considerable depth. Few of the accounts had been published before.

Two years later, seventeen fresh sections were described in a paper on some Suffolk well-sections,[1] and since then four others have been noticed in various publications.

As notes of thirty-one more have accumulated; as there is no opening for the printing of these, either in a Survey Memoir or in the publication of a local society (for there is no such publication); and as some of them have points of considerable geological interest, it is hoped that I may be forgiven for bringing matters of local detail (such as the following sections of twenty borings) before the Geological Society, which, as a rule, is hardly the proper place for them.

Though ready to take a somewhat extended view of a remark made by a former President, that papers of local character would find a more appropriate birth near the place of their conception, yet I think it better that such papers (at all events my own) should be born rather than strangled in embryo.

The object of this paper is to show how greatly our knowledge may be added to by wells or borings, and how sometimes these give results that could not have been expected.

Woodbridge.

If there is a place in Eastern Suffolk where one might reasonably expect to be able to foretell the depth to the Chalk, through some thickness of overlying beds, within a small limit of deviation, that place is Woodbridge; for we have published records of wells or borings at eight places in that town and in the adjoining village of Melton, which reach the Chalk with no great variation of depth, with one exception, and that only from considerable difference in the height of the ground.

A summary of the results may be given in a tabulated form, as follows, with the addition of the level of the Chalk-surface where it can be given:—

Place of section.	*Depth to Chalk.* Feet.	*Top of Chalk below Ordnance-datum.* Feet.
Hayward's Mill, close to the gasworks	48¼	33
Gall's, Thoroughfare	63	47
Hart and Wrinch, by the river..................	61½	35
Combe's Malting, near the Sun Inn............	52	19
Carter's, Thoroughfare	66	—
Melton Brewery	60	33
Melton Asylum, on high ground	126	—
Melton, for the Asylum, between the church and the railway-station	52	37

[1] Rep. Brit. Assoc. 1895 (Ipswich) pp. 436–40.

To these may now be added a well-section at a ninth place, which it will be seen gives a like result.

[In all the following sections words in square brackets have been inserted by the writer.]

Woodbridge. Castle Brewery (Messrs. Lockwood's). About 100 yards south-west of St. Mary's Church. 1899.

Made and communicated by Mr. F. Bennett, of Ipswich.

Cylinders had to be used, owing to the running sands. 80 feet of tube (internal diameter = 6 inches) driven to 83½ feet below the surface.

Good supply, from 8000 to 9000 gallons an hour.

		Thickness. Feet.	*Depth.* Feet.
Made-up soil		4	4
[Red Crag.]	Running sand	7	11
	Red Crag	4	15
[London Clay.]	Blue clay	31½	46½
[Reading Beds, 28 feet.]	Running sand	5½	52
	Brown clay	3½	55½
	Sandy loam	5	60½
	Light-coloured running sand	5	65½
	Sandy loam	5½	71
	Mottled clay	3½	74½
Chalk		120½	195

In the three of these cases where we are without information as to the relation of the top of the Chalk to Ordnance-datum, there can certainly be little difference from the other six, and we may take it that there is a variation of only 30 feet.

In some cases, unfortunately, the topmost beds are unrecorded, being pierced in old wells; but in no case is the depth to Eocene beds more than 40 feet (probably not reaching that figure), except in the one case at a high level, where as much as 74 feet of Drift and Crag were found, though how much of each is unknown.

It is clear, therefore, that we have here as much regularity as can be expected; and the newly-formed Waterworks Company was therefore justified in looking forward to a result in accordance with what had gone before, in making its trial-boring in the town, on low ground, and at no great distance from some of the existing borings.

But the following section shows a very different state of things, with a depth to Eocene beds of 133¾ feet, and a thickness of Crag much greater than any before known in the neighbourhood; about double, indeed.

It may be useful to add an analysis of the solid contents of the water, which shows that it cannot be classed as a Chalk-water.

Woodbridge. Trial-boring for the Waterworks Company. About 150 yards north of the Gasworks. 1901.

18 feet above Ordnance-datum. Rest-level of water 18 feet down.

Made and communicated by Messrs. Isler & Co. (Remarks in parentheses from notes on specimens, by Mr. H. B. Woodward.)

Yield tested, January 6th to 14th, 1902, and found to be from 975 to 1050 gallons an hour. Before pumping, the water stood 18 feet down; during pumping, 28½ feet.

Lined with 100 feet of 6-inch tubes, 4 feet below the surface; with 140 feet of 5-inch tubes, 2 feet below the surface; and with 205 feet of 4-inch tubes, 6 feet below the surface.

		Thickness. Feet	inches.	*Depth.* Feet	inches.
Soil		2	0	2	0
[Drift.]	Sand	4	6	6	6
	Gravel and flints	3	0	9	6
	Loamy sand (sandy loam)	4	0	13	6
	Sand	2	6	16	0
	Gravel	3	5	19	5
	Sand and shingle (loamy gravel)	4	0	23	5
	Mottled sand (somewhat loamy)	6	0	29	5
	Sand and shingle (fine gravelly sand)	8	0	37	5
[Crag, 95⅓ feet.]	Grey sand (dark brown silty sand)	1	0	38	5
	Fine sand (shelly sand)	7	0	45	5
	Fine sand, shingle, and Crag (gravelly sand)	60	7	106	0
	Black mud (fine gravelly loam)	1	6	107	6
	Crag with shells (shelly sand, *Turritella*)	25	3	132	9
[London Clay, nearly 20 feet.]	Claystone (septaria)	0	9	133	6
	Blue clay (stiff grey clay)	15	4	148	10
	Sand and pebbles	3	9	152	7
[Reading Beds, nearly 41 feet.]	Dark sand (grey firm sand, slightly loamy)	6	5	159	0
	Yellow sand and clay (brown sand)	15	9	174	9
	Blue clay (grey)	2	3	177	0
	Fine yellow sand (brown)	16	6	193	6
Chalk (and flints)		55	6	249	0

A section in the hands of Mr. C. E. Hawkins makes the depth to the Chalk 194½ feet. The division between Drift and Crag is not certain, nor is that between London Clay and Reading Beds.

Analysis by Dr. T. Stevenson, January 1902, in grains per gallon.

Sodium-chloride	12·39
Potassium-chloride, traces.	
Sodium-sulphate	4·08
Calcium-nitrate	12·09
Calcium-sulphate	10·66
Calcium-carbonate	18·05
Magnesium-carbonate	4·05
Oxide of iron, slight trace.	
Silica	·92
Total solid residue	62·24 (given as 62·44).

Ammonia, trace.
Albuminoid or organic ammonia .... ·0035
Oxygen required to oxidize the organic matter . ·0090

Hardness: temporary 21°, permanent 16°·5, total = 37°·5.

A saline hard water unsuited for washing purposes; also not good for dietetic purposes.

'The organic purity is high and there are no signs of recent contamination. But the nitrates are excessive: indeed in such quantities that, coupled with the objectionable salinity, force to the conclusion that the water is unfitted for a public supply.'

Still more recently, another boring has been made, on the high ground; and the section of this will be seen to agree with the older Woodbridge wells, allowing for difference of level.

Woodbridge. Waterworks. Trial-boring, Bredfield Road. 1902.

Made and communicated by Messrs. Isler & Co.

Well 10 feet; the rest bored. Lined with 165 feet of tube, 10 inches in diameter, from 10 feet down.

126 feet above Ordnance-datum. Rest-level of water 108 feet down. Yield=about 11,000 gallons per hour.

		Thickness.		*Depth.*	
		Feet	inches.	Feet	inches.
	Soil or made ground	3	0	3	0
[Drift and Crag.]	Sand and shingle, or sand and gravel	64	0	67	0
	Red Crag	13	0	80	0
	Light-coloured Crag	4	0	84	0
[London Clay.]	Blue claystone	1	2	85	2
	Blue clay (? sandy in part)	34	10	120	0
[Reading Beds, 35 feet.]	Mottled clay (a specimen is grey and red)	?16	6	136	6
	Sandy clay	12	0	148	6
	Green sand	3	0	151	6
	Green-coated flints	3	6	155	0
	Chalk and flints	119	0	274	0

Turning back to the one exceptional section, out of the eleven wells, the question arises, How has this unexpected thickness of Drift and Crag (the precise division between which is here of small moment) been preserved? Four explanations suggest themselves.

Firstly, a deep hollow or channel. This would serve, were it a case of Drift only; but we have to deal also with Crag, and it is hard to conceive of this filling so deep a hollow, worn out in lower beds. Moreover, we have also Eocene beds, and with them such an explanation is out of the question: they must have been let down in some way.

This last consideration suggests the explanation of a huge pipe in the Chalk, into which the overlying beds have been let down, through the dissolving-away of the Chalk. But such a pipe would so far exceed anything that is known, and is so unlikely to occur where the Chalk has a fair capping of Tertiary clays, that one hesitates to accept it. However, it might account for the great thickness of Crag, as compared with what is seen along the outcrop in the neighbourhood.

A third explanation would involve disturbance of the beds, presumably by a fault; but against this is the fact that there is no

sign of anything of the sort in the surroundings, though we do not know what there may be in the river-channel.

Another view is that we may here have the result of a landslip, which took place before the bordering hills had been eroded back as far as now. This, too, would explain the thickness of the Crag, etc.; but a landslip would not reach to a goodly depth below sea-level, as does the occurrence with which we are dealing.

Of the four explanations noticed that of a fault seems the best, but I am not satisfied with any. Of course it is open to us to make a combination of two or more of them; and I leave my brother-hammerers to make the mixture, according to taste.

Lowestoft and the Neighbourhood.

It is of interest to know the depth to the Chalk, as well as the nature and thickness of the beds above it, here, especially as it was said, several years ago, that the Chalk had been reached at some 60 feet below the sea-level at Lowestoft. This seemed to be most unlikely, as at Yarmouth, about 8 miles to the north, the depth to the Chalk is 526 feet, and at Southwold, about 11 miles southward, it is 323 feet. The depth at Lowestoft ought therefore to come between those figures, and nearer the former than the latter, if the beds are fairly even. It should be noted that the depth to the London Clay is 166 feet at Yarmouth and 184 feet at Southwold.

It is pleasant to find that in this case the inference is justified, as may be seen from the following sections, which are also satisfactory in another way. Mr. F. W. Harmer and Mr. Clement Reid have lately inferred that at Lowestoft it is likely that the Crag should extend down to a depth of about 200 feet, which conclusion is now justified, with something to spare.

A note of the first section (to the depth of 180 feet) was given by Mr. Reid in the 'Summary of Progress of the Geological Survey for 1898,' but without details.

Lowestoft. Youngman & Preston's Brewery, 69 High Street, at the foot of the old cliff. 1897.

About 20 feet above high-water level.

Made and communicated by Messrs. Isler & Co. (Remarks in parentheses from notes on specimens, by Mr. Clement Reid.)

Water-level 15 feet down. Unsuccessful.

	Thickness. Feet.	*Depth.* Feet.
Made ground	5	5
Sand (clean, gravelly; dune?)	8	13
Pebbles (recent beach)	4	17
Sand (clean buff)	20	37
Blue clay [? Chillesford]	24	61
Sand	9	70
Clay	8	78
Sand	127	205

Below 17 feet Mr. Reid's account (for which I have to thank the Geological Survey) differs, being more detailed and as follows:—

	Thickness. Feet.	Depth. Feet.
Clean buff sand	28	45
Blue silt	19	64
Coarse gravelly sand	1½	65½
Brown silt	14	79½
Bluish sand	13	92½
Shingle	½	93
Gravelly sand (*Mytilus*, *Mya*, *Cyprina*, at 120 feet; *Trophon* at 137; *Mya* at 150; *Cyprina* at 153)	73½	166½
Gravelly sand, full of fossils:—*Aporrhais pes-pelecani*, *Littorina littorea*, *Trophon antiquus* (dextral), *Astarte compressa*, *A. sulcata*, *Cardium*, *Cyprina islandica*, *Mactra ovalis*, *Mya arenaria*, *Mytilus*, *Pecten opercularis*, *Pectunculus glycimeris*, *Tellina obliqua*, fish-bones	33½	200

From this it is clear that the Crag reaches to a depth of over 200 feet. The next section shows that it goes down to about 240 feet.

Lowestoft. Ice-works, near Lake Lothing. 1902.

Made and communicated by Messrs. Tilley. (Remarks in parentheses made from specimens.)

A good supply of water was got between 480 and 550 feet down, but unfortunately it contained much magnesia. A fresh set of tubes was driven down to 490 feet, to shut off this water. At that depth the Chalk is practically waterless.

		Thickness. Feet.	Depth. Feet.
[Drift.]	Red loamy gravel	12	12
	Fine light-coloured sand (specimen rather coarse)	13	25
	Grey sand (light-coloured), with stones	10	35
	Light-coloured sand (fine), with stones	7	42
	Coarse grit with stones (flint-shingle)	2	44
	Light-brown sand (with some small bits of flint)	12	56
	Sandy blue clay (brownish-grey, micaceous)	2	58
	Sandy loam (fine, grey, compacted loamy sand)	4	62
	Dark-grey sand	1½	63½
	Grey sand (browner than the above)	1½	65
	Red sand (pale brown, with some more or less rolled flints)	4½	69½
[? Chillesford.]	Blue clay (grey and brownish-grey, rather sandy, micaceous clay)	4½	74
[Crag, 166 feet.]	Sandy loam (grey, compacted loamy sand)	2	76
	Dark-grey sand (light-grey)	10	86
	Dark loamy sand (light-grey, compacted loamy sand)	14	100
	Sharp sand (light brownish-grey)	38	138
	Sharp sand (grey), with shells	43	181
	Fine silty sand (grey, compacted)	5	186
	Sharp sand, with shells	42	228
	Mild clay, with shells (greenish-grey clayey sand)	12	240

		Thickness. Feet.	Depth. Feet.
[London Clay, 160 feet.]	Strong, light-coloured clay (greyish sandy clay)	2	242
	Sandy clay (greenish-grey and brownish-grey clayey sand, bits of shells at 243 feet: ? carried down)	8	250
	Strong dark clay (brown, bits of shells: ? carried down)	2	252
	Sandy clay with bastard flints (brown, bits of shells at 253 feet: ? carried down)	5	257
	London Clay, with yellowish rock at 310 feet 6 inches to 311 feet 4 inches, and grey rock, very hard (septarian), at 327 to 328½ feet and 340 to 340¾ feet (specimen of brown clay from top part, of septarian stone at 303 feet, of brownish flint at 310 feet)	143	400
[Reading Beds.]	Mottled clay (at 400 feet, curious dark bluish- and greenish-grey; at 435 feet, grey with greenish specks; at 438 & 446 feet, reddish mottled; at 447 feet, buff earth, ? very finely divided sand, with some brownish clay; at 447½ feet, brown clay; at 455 feet, very dark grey with some red bits; at the bottom very dark-grey clay, with some green sand and green-coated flints)	75	475
Chalk		75	550

From a specimen of the shelly sand, between 138 and 181 feet deep, Mr. E. T. Newton determined the following fossils, a result which, as he says, 'is better than could be expected from such ground-up material.' He adds that 'the bed must be very rich, and looks like being Red Crag.'

Trophon antiquus.
Trochus (?).
Turritella (?).
Cardium.
Mytilus edulis.
Pecten opercularis.
Tellina obliqua.
T. prætenuis.
Venus ovata.
Fragments of other lamellibranchs.
Cupularia sp.
Cellepora sp.
Salicornaria (?).
Echinocyamus pusillus.
Spatangus sp. (fragment)
Balanus sp.

Further information as to the great depth of the newer Tertiary beds in this neighbourhood is given by three other well-sections, respectively about 2 miles westward, about 4 miles southward, and about 6 miles south-south-westward of Lowestoft.

One of these, near Oulton Broad Station, has been kindly communicated by Mr. C. E. Hawkins, from a rough note taken by him; but he forgets from whom he had the information, so that we cannot pin our faith to its absolute correctness. It is as follows, with the probable classification added :—

		Thickness. Feet.	Depth. Feet.
[Drift.]	Sand and gravel	18	18
	Running sand and water	30	48
[? Chillesford.]	Blue clay	14	62
[Crag.]	Grey 'blowing' sand	117	179
	Yellow clay	20	199
	'Blowing' sand	43	242
[London Clay.]	Clay. Iron-pan, 4½ inches thick, 278 feet down; and another, 14 inches thick, 16 feet lower [? septaria]	73	315

For the following more detailed section, at Kessingland, I am indebted to the Geological Survey. Should the Crag here be of a thickness similar to that which has been proved at Lowestoft, it would reach down to about 250 feet.

Kessingland. Trial-well and boring. For public supply. In field No. 270 of the Ordnance Survey 25-inch Map. 1899.

Communicated by Mr. F. H. Anson, and from specimens noted by Mr. Clement Reid, who has also classified the beds.

About 70 feet above Ordnance-datum. Shaft 60 feet, the rest being a boring 8 inches in diameter.

		Thickness. Feet.	Depth. Feet.
	Soil, earthy loam	1½	1½
Boulder-Clay.	Yellow Boulder-Clay, with chalk	13	14½
	Lead-coloured Boulder-Clay, with chalk	13½	28
Glacial.	Fine-grained laminated sand, with mica; the bottom 6 inches being more ferruginous	8½	36½
	Fine chalky sand	3½	40
Probably Glacial.	Subangular gravel (flint, quartz, etc.)	20	60
	Brown gravelly sand	½	60½
	Ferruginous sand and small stones	10	70½
Chillesford Clay, 16½ feet.	Ferruginous micaceous loam	2	72½
	Grey micaceous loam	7½	80
	Grey, more micaceous loam	5	85
	Grey micaceous loam, harder and sandy	2	87
Crag.	Grey sand and small stones	11	98
	Gravel (flint-pebble & subangular quartz)	1	99
	Grey sand, with fragments of *Mytilus*	31	130
	Grey silty sand, with *Littorina littorea*, *Purpura lapillus*, *Tellina obliqua*, and *Cyprina islandica*	5	135
	Silty micaceous grey sand, with *Tellina*	13	148
	Grey sand, the bottom 7 feet with *Mytilus* and *Tellina prætenuis* (?)	13	161
	Hard, greenish-grey, micaceous loam	1½	162½
	Greenish-grey, micaceous, silty sand	1½	164
	Grey silty sand, somewhat coarser, with a few shell-fragments	16	180

A letter (of September 1900) from Messrs. Tilley, who were called in after the work was finished, gives the following further information:—The water-level was 61 feet down. From the deep

boring practically no water was got; but from a fresh boring, put down by them to the depth of 80 feet (from the surface), about 9 gallons a minute were obtained.

Lastly, we have a section at Benacre, where, if the Crag is about as thick as at the Southwold boring, some 5 miles south (where it has been proved to have a thickness of 147 feet), it should reach to a depth of over 200 feet.

Benacre. The Hall. 1900.

Made and communicated by Messrs. Tilley.
About 60 feet above sea-level.
Water from the sand and gravel from 38 to 43 feet down. Below 57 feet no water worth speaking of.

		Thickness. Feet.	*Depth.* Feet.
	Soil	2	2
[Glacial Drift.]	Boulder-Clay	19	21
	Loamy sand	1	22
	Sand	16	38
	Fine gravel	3	41
[? Drift.]	Loamy sand	2	43
	Dead sand	9	52
	Live sand and water (about 3 gallons a minute)	5	57
[? Chillesford Clay.]	Light-coloured loam	5½	62½
	Dark loam	½	63
	Light-coloured loam	9	72
[Crag.]	Dead sand (shells and very little water)	18	90
	Sand	73	163

Various.

The primary object of this paper has now been fulfilled. But there are a few other Suffolk sections that should, I think, be recorded in print, so as to be accessible to geologists. Accounts of these now follow, in alphabetical order of places. The first is not new, but the private Report in which it is printed can only be seen with difficulty. It corrects and adds to an earlier record.

Boulge. The Hall. The well was deepened and the borehole made about 1873.

About 116 feet above Ordnance-datum.
Letter from Mr. O. T. Gibbons in Mr. G. Hodson's Second Report (Suffolk Asylum Water-Supply), 1890.
Shaft 79 feet, the rest bored; 6 inches in diameter at first, then 4 inches.
Water, from the Chalk, rose to within about 20 feet of the top of

the bore-pipe. Supply plentiful. In the well there was plenty of water from the 'coprolite white sand;' but it smelt badly, and was not fit for use.

		Thickness. Feet.	Depth. Feet.
[Boulder-Clay.]	Clay	49	49
[Drift ? & Crag.]	'Coprolite white sand'	50	99
[London Clay, 56 feet.]	London Clay	50	149
	[? Basement-bed.] Green sand, similar to turnip-seed	6	155
[Reading Beds, 40 feet.]	Yellow clay	25	180
	Green sand, as above	15	195
Chalk		29	224

This does not agree with the short note reproduced in the Geological Survey Memoir on 'The Geology of . . . . . Woodbridge,' p. 50 (1886), which makes the depth to the Chalk 160, and in the Chalk 90 feet. The above more detailed account is presumably the more correct. The water was condemned on analysis.

Brettenham Park. By some outbuildings west of the Hall. 1901.

Communicated by Mr. T. C. T. Warner, M.P. (from a statement which was given him by the borers), with some notes from the Rev. Edwin Hill.

About 280 feet above Ordnance-datum.

Shaft 139 feet, the rest bored. An excellent supply of water, to within 140 feet of the surface.

		Thickness. Feet.	Depth. Feet.
[Glacial Drift.]	Blue Boulder-Clay, with chalk-stones. A specimen from the depth of 130 feet slightly brownish	141	141
	Rough red sand	16	157
	Loam-sand with grey clay	5	162
	Fine red running sand	30	192
	Grey clay mixed with red sand	6	198
	Rough red sand with shells; some water with a bad smell	15	213
	Hard rocky substance	4	217
	Conglomerates	5	222
	Plastic clay with flints (apparently Boulder-Clay)	90	312
Chalk and occasional beds of flint		232	544

This is of interest in showing a great thickness of Drift, the greatest I think recorded in the county. The site, in the midst of a wide tract of Boulder-Clay, is one where naturally the Chalk would be expected to be at a considerable depth, but not nearly so much as 312 feet.

Bungay. For the Parish Council. Since 1895.

Bored and communicated by Messrs. LeGrand & Sutcliff.

45 feet above Ordnance-datum. Water-level $28\frac{3}{4}$ feet down.

		Thickness. Feet.	Depth. Feet.
Dug well (the rest bored)		—	$31\frac{3}{4}$
[? Drift or Pebbly Series.]	Greenish-grey sand and stones	$4\frac{1}{2}$	$36\frac{1}{4}$
[? Crag.]	Greenish-grey 'blowing' sand and shells, with thin bands of blue clay and pebbles	$66\frac{3}{4}$	103
Chalk and flints		67	170

This gives more information than the previously published six sections in the town, though not so much as that at Broome Place, some 2 miles away.

East Bergholt. For Mr. A. D. Halford.

Made and communicated by Mr. F. Bennett, of Ipswich.

Old well 40 feet, deepened to 100. Intended to make it deeper, but stopped by running sand, about a foot thick, at that depth (20 feet of iron-cylinders at the bottom). A bore, of 4 inches diameter, put down by Messrs. Owen (about 1892), to the depth of 242 feet.

Water stands about 95 feet down. Supply of good quality, about 1600 gallons an hour.

In the old well clay is said to have been met with a few feet down, and continued, of various colours.

		Thickness. Feet.	Depth. Feet.
Old well		—	40
[London Clay.]	Light-coloured clay	20	60
	Dark clay	54	114
	Sandy loam [? basement-bed]	9	123
[Reading Beds.]	Stiff clay	2	125
	Clay	41	166
Chalk		$158\frac{1}{2}$	$324\frac{1}{2}$

This section gives more exact information than the two very old ones already published.

The following two sections at Hadleigh give a good deal more information than what we have from the six already published, and the second one seems to point to a channel of Drift.

Hadleigh. Mr. T. Wilson's Maltings. Since 1895.

Bored and communicated by Messrs. LeGrand & Sutcliff.

Water-level 78 feet down.

		Thickness. Feet.	Depth. Feet.
Well (the rest bored)		—	48
[? All Reading Beds.]	Brown sand	7	55
	Blue clay	5	60
	Green sand	7	67
	Light-blue clay	4	71
	Coarse brown sand	4	75
	Coarse grey sand	5	80
	Blue clay	1	81
	Sandy blue clay	7	88
	Loamy sandy clay	2	90
	Mixture, sandy clay	4	94
	Mixture, green sands	4	98
	Flints	2	100
[Upper Chalk.]	Chalk (no flint)	140	240
	Chalk and flint	58	298

Hadleigh. Messrs. Woods & Co. Since 1895.

Made and communicated by Messrs. LeGrand & Sutcliff.
90 feet above Ordnance-datum. Water-level 16 feet down.

		Thickness. Feet.	*Depth.* Feet.
	Made earth	4	4
[? All Drift.]	Gravel and water	6	10
	'Clay chalk and stone drift'	2	12
	Yellow clay and chalk	4	16
	Blue clay and chalk	37	53
	Loamy sand and water	13	66
	Blue clay and chalk	24	90
[Upper Chalk.]	Putty chalk	25	115
	Chalk	67	182
	Chalk and flints	38	220

Hitcham Street. Boring for Public Water-Supply. 1901.

Communicated by Mr. E. S. Cobbold. (Remarks in parentheses from specimens.)

About 175 feet above Ordnance-datum.

		Thickness. Feet.	*Depth.* Feet.
	Surface-material, Boulder-Clay	12	12
[? All Drift.]	Gravel and sand	18	30
	White sandy silt	15	45
	Pale greenish sand (specimen fine, buff)	15	60
	Dark mud, smelling like a ditch	5	65
	Dark sandy mud, varying in coarseness	13	78
	Dark sand, with shell fragments; occasional flint and other pebbles. A few perfect shells, waterworn (*Mya?* at 87 feet; *Mya, Purpura, Tellina* at 97 feet)	20	98
	Dark sand, rather finer; no shells	? 2	100
	The like; few shell-fragments	? 4	104

The shells are not suggestive of Crag; and the section, as the Rev. Edwin Hill remarks (in a letter to me), 'is interesting as revealing a buried valley.'

Ipswich. Messrs. Burton & Saunders, College Street, adjoining Messrs. Turner's Foundry.

Made and communicated by Mr. F. Bennett.

Measured from the basement-floor, which is about 6 feet below the street-level. 153 feet of tubes, of 6 inches internal diameter, were driven.

		Thickness. Feet.	Depth. Feet.
	Well	—	9
[? All Drift.]	Light-coloured running sand	$9\frac{1}{2}$	$18\frac{1}{2}$
	Light-coloured loam	$30\frac{1}{2}$	49
	Sand and hard chalk in lumps, or sort of stone	32	81
	Light-coloured loam	$16\frac{1}{2}$	$97\frac{1}{2}$
	Light-coloured running sand	2	$99\frac{1}{2}$
	Blue clay	$2\frac{1}{2}$	102
	Loam with flints	$7\frac{1}{2}$	$109\frac{1}{2}$
	Rough sand with chalky stones, as above	3	$112\frac{1}{2}$
	Stiff loam, with chalk and flint-stones	$12\frac{1}{2}$	125
[? Reading Beds.]	Sand	4	129
	Flint-bed	1	130
Chalk.	Flints met with at 32 levels, from about 212 feet to the bottom	$191\frac{1}{2}$	$321\frac{1}{2}$

The interest of this section lies in its corroborating the evidence for a deep channel of Drift, given by the section at St. Peter's Quay, New Mill, showing a depth of 127 feet to the Chalk, whereas at Messrs. Turner's foundry (close by to the west) it is but 70 feet.[1] All three show a considerable thickness of Drift, the top of the Chalk being lower than on the rather higher ground northward, as the following section, as well as the Geological Survey map, shows.

Ipswich. Messrs. Pretty's Stay Factory, about 200 yards north of the Cornhill. Top level with the basement-floor. 1896.

Made and communicated by Mr. F. Bennett.

25 feet of cylinders, of $4\frac{1}{2}$ feet diameter, to the depth of 31 feet $4\frac{3}{4}$ inches. Brickwork built on this for $6\frac{3}{4}$ feet in height. A tube, of 6 inches internal diameter, driven $16\frac{1}{4}$ feet into the Chalk.

A supply of 10,000 gallons an hour taken; 13,000 were got in the trial-pumping.

		Thickness. Feet	inches.	Depth. Feet	inches.
[? Drift.]	Red earth	12	6	12	6
[? Reading Beds.]	Running sand	4	0	16	6
	Mottled clay	11	6	28	0
	Green sand	3	6	31	6
	Mottled clay	0	8	32	2
	Light-coloured running sand	0	6	32	8
	Sand stone	1	10	34	6
	Running sand	10	0	44	6
	Blue clay	8	0	52	6
Chalk.	Chalk and flints	1	0	53	6
	Chalk	196	6	250	0

Shotley. West Valley, close to the Orwell. Trial-boring, for the Marquis of Bristol. 1900 (?)

Made and communicated by Mr. F. Bennett, and from Mr. T. Miller, of Ipswich.

Timber-shaft 14 feet, the rest bored (July 12th–18th).

[1] 'The Geology of the Country around Ipswich, etc.' Mem. Geol. Surv (1885) pp. 117 & 118.

		Thickness. Feet.	Depth. Feet.
Soil		$\frac{3}{4}$	
[LONDON CLAY.]	Brown clay	2	$2\frac{3}{4}$
	Light-coloured loamy sand	$5\frac{1}{4}$	8
	Brown clay	6	14
	London Clay, with 3 inches of soft rock at the base	$3\frac{3}{4}$	$17\frac{3}{4}$
	Blue clay, with 3 inches of hard rock at the base	$7\frac{1}{2}$	$25\frac{1}{4}$
	Close blue clay	$21\frac{1}{4}$	$46\frac{1}{2}$
	Dark loam	$3\frac{1}{2}$	50
	Light-coloured loam	7	57
	Stiff brown clay	5	62
	Light-coloured loam	6	68
[READING BEDS, 32 feet.]	Mottled clay	$3\frac{1}{2}$	$71\frac{1}{2}$
	Light-coloured stiff loam	3	$74\frac{1}{2}$
	Strong blue clay	$1\frac{1}{2}$	76
	Strong brown clay and marl	$4\frac{1}{2}$	$80\frac{1}{2}$
	Mottled clay	$8\frac{1}{2}$	89
	Mottled loam	$3\frac{1}{2}$	$92\frac{1}{2}$
	Green loam	1	$93\frac{1}{2}$
	Mottled clay, bright red and green	$4\frac{1}{2}$	98
	Green clay with flints	2	100
Hard CHALK and flints		4	104

This shows a greater depth to the Chalk than at the older well at the brickyard, where 17 feet of Crag were found, only 8 of London Clay, and 45 of Reading Beds.[1]

Stansfield. 1895.

Made and communicated by Mr. G. INGOLD.

302 feet above Ordnance-datum.

Shaft $101\frac{1}{2}$ feet, the rest bored. Water rose to within $94\frac{1}{2}$ feet of the surface.

		Thickness. Feet.	Depth. Feet.
Mould		2	2
[DRIFT.]	White clay	$1\frac{1}{2}$	$3\frac{1}{2}$
	Loamy sand, with water	1	$4\frac{1}{2}$
	Blue and brown clay	$8\frac{1}{2}$	13
	Dark-grey sand	4	17
	Blue clay. Large boulder at 60 feet. Sandy veins at $101\frac{1}{2}$ feet	91	108
[? DRIFT or READING BEDS.]	Mottled clay	13	121
	Pale-green sand	3	124
Yellow CHALK		12	136

The description of the two beds next above the Chalk reads as if a patch of Reading Beds had been found beneath the Drift.

A similar suggestion of the presence of Reading Beds under the Drift, beyond where they have been mapped, was given by a well at Foxearth, in Essex,[2] and that is the nearest record of any such

[1] 'Geology of Ipswich, etc.' Mem. Geol. Surv. (1885) p. 122.
[2] 'Essex Naturalist' vol. vi (1892) p. 51.

occurrence, the mass of the Eocene Tertiaries being more than 7 miles from Stansfield, at the nearest, while Foxearth is over 5 in the same direction (south-east).

Should the beds just above the Chalk in these cases prove to be Eocene, it will show how doubtful it is what next underlies the thick Drift in many places in these parts.

Woolverstone. Mr. C. H. Berners. Since 1895.

Made and communicated by Messrs. LeGrand & Sutcliff.
95 feet above Ordnance-datum. Water-level 93 feet down.

		Thickness. Feet.	*Depth.* Feet.
	Soil	2	2
[Drift.]	Sand	4	6
	Sandy gravel	6	12
[London Clay, 59 feet.]	Brown clay	6	18
	Sandy blue clay, with 9 inches of claystone at the base	$13\frac{3}{4}$	$31\frac{3}{4}$
	Blue clay	$7\frac{1}{4}$	39
	Sandy blue clay, with 15 inches of claystone at the base	$9\frac{3}{4}$	$48\frac{3}{4}$
	Sandy clay	$22\frac{1}{4}$	71
[Reading Beds, $34\frac{1}{2}$ feet.]	Hard dark sand	4	75
	Yellow sandy clay, with 21 inches of hard claystone at the base	$7\frac{1}{4}$	$82\frac{1}{4}$
	'Blowing' sand	$11\frac{3}{4}$	94
	Hard blue clay	6	100
	Coloured [mottled] clay	$4\frac{1}{2}$	$104\frac{1}{2}$
	Green flints	1	$105\frac{1}{2}$
[Upper Chalk.]	Soft chalk	$10\frac{1}{2}$	116
	Chalk and flints	134	250

Discussion.

The Rev. E. Hill said that the wells also furnished information as to underground water-level. The depth at Woodbridge could be explained simply by a buried channel, such as often lay below existing valleys. The paper mentioned such at Ipswich and Hitcham, and Brettenham Park might be connected with the latter. In the remarkable section at Brettenham Park he thought the evidence insufficient for describing as Glacial everything above the Chalk. The beds there next below the Chalky Boulder-Clay probably agreed with corresponding beds at Hitcham, and these were unlike any thing he knew in the coast-sections. Tertiaries did exist in the neighbourhood, as at Sudbury. Woolwich and Reading Beds might well be called 'plastic clay' by a well-sinker, as was the lower clay here. He thought that judgment must be suspended.

Mr. Horace B. Woodward said that he had seen samples from the Woodbridge well, and had considered that a trough-fault best explained the structure. With regard to the Brettenham well, he agreed with the previous speaker that the 'plastic clay' was very likely to belong to the Reading Beds. No definite outcrop of Lower Boulder-Clay was known in West Suffolk, and the Author had

recorded the presence of Reading Beds in a well to the south-west of Brettenham.

Prof. Boyd Dawkins accepted the first speaker's view as to these sections, and called attention to the fact that the Boulder-Clay series was irregular in thickness, because it was deposited on a land-surface of hill, valley, and ravine, levelling up the valleys, and being thickest in the deepest valleys. This was the case throughout the British Isles, on the west as well as on the east of the Pennine chain.

Dr. R. L. Jack said that the point which had appealed to him most forcibly was the evidence furnished by the wells in question regarding former erosion, some channels, or at least depressions, having been recognized even in the Crag. Ancient depressions, whether filled up with Glacial Drift or merely with river-gravels, seemed to afford evidence of a pre-existing higher level of the land with reference to the sea, since rivers could not scoop out valleys below sea-level, except perhaps to a limited extent by 'pot-holing' action. Glaciers confined in valleys might, in his opinion, grind out basins to any depth, but he could not see how an extensive ice-sheet could grind out depressions far away from the mountainous region which set it in motion. It was unfortunate that some of the Suffolk wells had, after attaining a certain depth, been continued as bores; and that with a plant which did not produce a core, but merely pounded up the strata to chips and dust. He could have wished—and no doubt the owners of the land would agree with him—that the Drift in the Suffolk depressions had contained payable gold, for then, as in Australia, these would have been followed and traced out. In Victoria, for instance, rich deep leads had been followed for many miles, and whole river-systems, differing from the present ones, had been mapped out. In some of these channels, river-alluvia had been covered by one, two, or even three successive flows of basaltic lava. In some Queensland districts, where gold and sapphires occurred in the Tertiary drifts, fragments of river-courses had been traced for considerable distances by the connection of series of hilltops formed by the preservation of portions of the drifts through the hardness of the basalt, which at one time must have been a continuous sheet of lava. In the case of the artesian wells of the West of Queensland (to which the President had invited attention) little light had been thrown by the bores on the depth of the superficial drifts, partly because the plant employed did not take out cores. But he believed that, as a rule, there was nothing above the Cretaceous rocks which carried the artesian water except the débris of the shales decomposed in place. Some information regarding these wells might be of interest. In the last 17 years 202 miles of bores had been sunk, to depths varying up to 5045 feet. 532 successful bores gave an annual outflow of 128,022,767,710 gallons. The temperature of one of the bores was 196° Fahr. Such a number of flowing wells, even though they were merely dotted over an enormous area, could not fail to have mitigated to some extent the disastrous effects of the seven years' drought through which the country had lately passed. It was

happily at an end, he thought, as cable-messages received only the previous day were understood to announce the break-up of the drought.

Mr. Hopkinson, referring to the President's remark that there were other counties for which the well-sections had not been published, instanced Bedfordshire as one without a Natural History Society to publish them. At Sandy, in that county, the Lower Greensand forms a hill rising about 120 feet above the plain, in which, 2 miles to the south-west, a boring passed through 104 feet of Boulder-Clay resting upon the Oxford Clay. The only evidence that the Upper Lias underlies the county is to be found in unpublished well-sections at Sharnbrook; and he knew of two wells in the Lower Greensand at Clophill, within 30 feet of each other, one of which yielded excellent drinking-water, while the water from the other was utterly unfit to drink. He thought therefore that the Author would find sufficient points of interest in the well-sections of Bedfordshire to bring before the Society.

Capt. J. McK. Knight said that he had not found any evidence of old valley-beds in the Chalk yielding a supply of water, but believed that it came through fissures. He could instance one brewery on which a well 380 feet deep existed; within a short distance a new well was sunk. He was there at 4 o'clock in the afternoon, when the cylinders had been driven 2 feet into the Chalk, which had been reached at 202 feet: the stuff which was being lifted was milky. On the men coming to work the next morning, it was found that there was 80 feet of water in the well. It was thought that a pocket had broken in, and the pumps were sent for, but after pumping for a fortnight they could only reduce the water by 6 feet. It was therefore good enough to leave it alone. At another brewery he had sunk a well, and had had to go 580 feet before sufficient water was reached.

Dr. W. M. Tapp, while regretting that he was no geologist, stated that he was deeply interested in wells and well-sinking, and had been himself instrumental in starting the Woodbridge well. He felt the greatest difficulty in understanding why from their second well an abundant and pure supply of water should have been obtained, when it was surrounded by a ring of wells all producing indifferent water; this seemed to show how impossible it was to define the course pursued by underground water. Again, the tubes in the well referred to had stuck, owing to the presence of a hard siliceous rock, the nature of which was a mystery to him; the strength of the rock was shown by the fact that it held the tubes, which parted under the strain from hydraulic jacks capable of exercising a pressure of 130 tons.

The Author, in the first place, desired to express his thanks to all who had assisted him by so readily supplying information. He pointed out that at Woodbridge not only Drift-beds, but Crag and Eocene beds, had to be dealt with. He knew of no case in which Eocene deposits filled up deep valleys, nor of any really deep 'gouges' in the Crag. As to the so-called 'Plastic Clay' of Bret-

tenham, the supposititious existence of Eocene beds there at a depth of 200 feet would involve considerable disturbance or faulting. The simplest and easiest way out of the difficulty was to class all doubtful deposits of that nature with the Drift, which might be of great thickness. He agreed that if there was faulting at Woodbridge, it probably was trough-faulting. He had described a deep channel filled with Drift from evidence furnished by Essex well-sections: there was no sign of Glacial Drift at the surface in some cases, and yet the thickness of that deposit was 340 feet in one case, without the base being reached. The 'clay-stone' alluded to by the last speaker was probably a septarian mass in the London Clay. The varying water-yield of wells was not easily explicable. Systematic recording of well-sections was highly desirable; but this could only be carried out properly by a Government Department.

5. *The* Cellular Magnesian Limestone *of* Durham. By George Abbott, Esq., M.R.C.S., F.G.S. (Read December 3rd, 1902.)

[Abstract.]

The Permian Limestone covers about $1\frac{1}{4}$ square miles near Sunderland; it alternates with beds of marl containing concretionary limestone-balls, and attains a thickness of 65 feet or so. The cellular limestones frequently contain more than 97 per cent. of calcium-carbonate. Magnesium-carbonate occupies the interspaces or 'cells' of this limestone, and also the spaces between the balls. The hundred or more patterns met with in it can be arranged into two chief classes, conveniently termed honeycomb and coralloid, each with two varieties; and each class has four distinct stages, both classes having begun with either parallel or divergent systems of rods. The second stage is the development of nodes at regular distances on neighbouring rods; and these in the third stage, by lateral growth, become bands. Finally, in the fourth stage the interspaces become filled up. The upper beds are usually the most nearly solid. In the coralloid class the nodes and bands are smaller and more numerous than in the honeycomb class. In both classes tubes are frequently formed. The rods have generally grown downwards, but upward and lateral growth is common. A section of Fulwell Quarry is given..

Discussion.

Dr. Henry Woodward complimented the Author, not only upon his fine display of lantern-slides and photographs, but also upon having liberally presented to the Natural History Museum the very beautiful series of specimens which he had collected during many years. The Author had referred to the 'puzzle,' which, since the days of Sedgwick, still remained, as to how these structures came about. Surely, the giving of names to the varied forms which these remarkable inorganic bodies took on, did not advance us much. He (the speaker) thought that we should look at them, and at the flints in the Chalk, the clay-ironstone nodules of the Coal-Measures, the septaria of the London Clay, and the concretions in other clayey and shaly beds, as all due to the same set of causes. Water in the Chalk, charged with silica in solution, deposited that silica as flint-nodules or bands of flint along lines of stratification in the Chalk or in joints. So in other beds the iron was deposited, often around organisms; but not so much so at Sunderland, although Prof. Garwood had shown that fossil shells did occur in these calcareous concretionary beds. Prof. Rainey, as far back as 1857, had pointed out that, by introducing gum in solution into a fluid magma ready to crystallize out, the tendency to crystallize remained, but was frustrated or arrested by the gum-solution, and

the mineral matter formed into a concretion instead. He thought that this would, in a measure, account for the Author's specimens from Sunderland; but how all these varied forms of pseudo-crystalline bodies came about was a puzzle still, and the right persons to solve it were chemists and mineralogists.

Mr. A. P. Young remarked that, in trying to explain these structures, we were not bound to confine our attention to the present chemical constituents of the rock. The possible removal of gypsum and soluble salts so frequently associated with dolomite in the Zechstein formation must be taken into consideration. Instances were furnished by the Stassfurt beds and the Rauchwacke. Some of the Author's specimens showed druses which recalled similar cavities in the Rauchwacke containing the so-called 'asche,' a powder consisting chiefly of dolomite and calcium-sulphate.

Prof. Garwood congratulated the Author on the splendid series of photographs and specimens which he had exhibited and described. But he confessed that he had been disappointed in the slight allusions made to the mode of formation, among which he could not discover anything that was new, or that was contrary to what he, the speaker, had set forth in a paper in the 'Geological Magazine' for 1891, p. 433. He thought that the cause of the origin of the concretions was as obscure as of yore, and that the best that we could do at present was to put them down as 'organized accidents.' With regard to the suggestion of one of the speakers that a bulk-analysis should be made of the beds containing concretions and the non-concretionary beds interstratified with them, he would like to point out that he had made and published such analyses in the paper already mentioned, and that his results showed a remarkable correspondence in the percentage of magnesium-carbonate in the two beds, the relative amount of magnesium to calcium-carbonate in the one case being 40 to every 100 parts, and in the other 43. For fuller details he would refer the Author to the paper which he had quoted.

The Author expressed his thanks for the reception accorded to his paper.

6. Tin *and* Tourmaline. By Donald A. MacAlister, Esq., F.G.S. (Read November 19th, 1902.)

[Abstract.]

Cassiterite hardly ever occurs without tourmaline, although the latter is found without the former; hence it appears that tourmaline-producing constituents and influences are of wider range than are those of cassiterite. Boron-trioxide is an extremely common accompaniment of volcanic action, and there can be no doubt that it has acted powerfully in changing such original minerals as the micaceous and felspathic ingredients of crystalline rocks. From a comparison of formulæ representing tourmaline and felspar, it is evident that the act of tourmalinization has been accompanied by a loss of soda (which alone is capable of action on tin). The excess of boric acid (which is over and above that required for tourmalinization) will combine with this soda, forming metaborate and pyroborate of soda. The former, acting on disseminated tin-ore, might result in the production of sodium-metastannate and borax. The soluble metastannate is capable of being leached out of the magma, and, by a new reaction, tin-oxide may be precipitated and concentrated, sodium-metaborate being liberated. According to the principle underlying the cooling-curves of solutions, in all probability deposition of cassiterite would take place more rapidly at a certain stage in the process of cooling than at others.

Discussion.

Mr. J. H. Collins remarked that the Author did not refer to the somewhat extensive literature of the subject, and especially to the writings of Von Buch (1824), Daubrée, Foster, and others, which, as well as Daubrée's experiments, went to show that fluorine had played a great part in the production of schorl, as also in the origin of cassiterite and of kaolin, in Saxony, Cornwall, and other countries; so that while there was in these countries schorl without cassiterite and kaolin, there was not cassiterite or kaolin without schorl. A due consideration of these facts might perhaps lend support to the Author's hypothesis, at any rate as to the secondary deposition of cassiterite. Some attention should, however, be given to the fact that in Tuscany and in the Malay Peninsula cassiterite did undoubtedly occur in limestone unaccompanied by schorl, as also in the hornblende-rocks of Pitkäranta in Finland, and in connexion with the andesites of Bolivia.

Prof. Sollas thought this an interesting speculation and very suggestive for future investigation, which he hoped the Author would pursue both by experiment and observation.

Mr. T. H. Holland agreed with the previous speaker in welcoming a paper which, not claiming to explain every case, or to be a complete discussion of the well-known work of Élie de Beaumont,

Boase, Le Neve Foster, and others, was suggestive in offering another possible chemical explanation of the reactions by which tin-dioxide could be separated from solution in magmas containing alkaline borates. Although the deposition of tin is frequently an accompaniment of kaolinization, where fluorine has been active, kaolinization is not essential, as cassiterite occurs in perfectly fresh acidic pegmatites. But the consolidation of a pegmatite results in the exclusion of water to the final stages to such a degree that the last deposition of mineral matter may imitate the 'comby' structures of ordinary mineral veins; while the vapours set free begin to attack the crystals of early consolidation, and to produce results akin to secondary alteration. At some stages in this process the Author's supposed chemical reactions may occur, and the granting of one process for the separation of cassiterite does not exclude others that are chemically possible under changed physical conditions.

7. *The* MAGNETITE-MINES *near* COGNE (GRAIAN ALPS). By Prof. T. G. BONNEY, D.Sc., LL.D., F.R.S., F.G.S. (Read December 17th, 1902.)

THOUGH the magnetite-mines of Cogne in the Graian Alps are frequently mentioned, I have not succeeded in finding any detailed description of the relation of the ore to the adjacent rocks; so, as this seems to me interesting, I venture to publish a few notes made during the past summer when, in company with my friend the Rev. Edwin Hill, F.G.S., I spent some little time at the Hôtel de la Grivola in that village, where I had already twice halted for a night or two in my climbing days about forty years ago. These mines are said to have supplied ore to the Romans, and have certainly been worked since the beginning of the fourteenth century—though for many years past little or nothing has been done, not because of any failure in the ore, which is practically inexhaustible, but owing to the cost of placing it on the market; for though Aosta is now accessible by railway, it is between five and six hours' walk from that town to Cogne, and the road after the first 5 miles is only fitted for charrettes (country-carts). The mines, also, are not at Cogne, but high up on La Ruine Blanche, a spur of the Pointe de la Creia: three workings (according to my sheet of the Quadro di Unione, 1852) being on its southern face above the main valley, and one on its western flank above the Vallon de Grauson. After visiting the last-named and the most important of the others, we can well understand why they have been abandoned.

The Filon de Licone, or Le Grand Filon—one of the former group—and not much less than $2\frac{1}{2}$ hours of steady walking from Cogne (5033 feet), is 7667 feet above sea-level, by a rough mule-path; the other, the Filon de Larsine, is at a lower level, and nearer Cogne[1]; but part of the more direct path, owing to a fall of rock, is now in a very bad condition. The mountains on the side of the Val de Cogne consist of calc-mica-schists, hornblendic schists, and serpentines: the first varying from almost pure marbles (not common near Cogne) to rather conspicuously micaceous schists; the second (Grüner Schiefer), also rather variable, are generally fine-grained, of a distinctly green colour and schistose, but are sometimes more granular and dioritic. The serpentines I shall presently notice.

According to Cavaliere W. P. Jervis,[2] the magnetite forms

> 'un filone strato incassato tra il calcare bianco-giallognolo e gli schisti talcosi della zona delle pietre verdi; in cui sono numerose vene di minerale, divise da banchi di roccia serpentinosa.'

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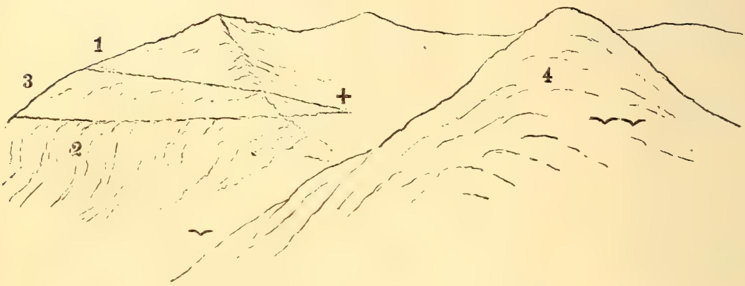
[1] I forgot to read my aneroid, and we did not walk direct to the mine from Cogne; but I should think that the height was not far from 6000 feet, and the distance by time about one half that of the other place.

[2] 'I Tesori sotterranei dell' Italia' pt. i (1873) § 211, p. 92.

I think that some details in this statement may be rendered more precise, and have no belief in the existence of a zone of 'pietre verdi' as a definite geological horizon. As I have elsewhere shown,[1] these green, more or less actinolitic schists are most abundant in the group which I have designated for purposes of reference 'the upper schists.' The latter vary from dark mica-schists, but slightly calcareous, and occasionally containing garnets, staurolites, etc., to nearly pure marble on the one hand, and to quartz-schists on the other. Among these the green schists are often abundant, being

Fig. 1.—*Position of the Filon Licone.*



[Diagrammatic sketch from the Vallon de Valeiglia.]

1, 2 = Certainly calc-mica-schist, probably going to the top of the hill above 1.
3 = Serpentine, the limits being made fairly distinct by the colour of the rough hillside due to small outcrops; it seemed to thicken towards the left.
The + indicates the position of the mine.
4 = Probably calc-mica-schist; there is possibly a small outcrop of serpentine at ∼∼.
Beneath ∼ is a ravine which runs up, dying out, rather to the right of the mine.

not seldom clearly intrusive.[2] Similar rocks also occur, though more rarely, among the underlying gneisses, so that, at any rate in most parts of the Alps, the green schists are pressure-modified diabases, generally intrusive in the calc-mica-schist group, the serpentines being also intrusive, sometimes into the one, sometimes into the other.

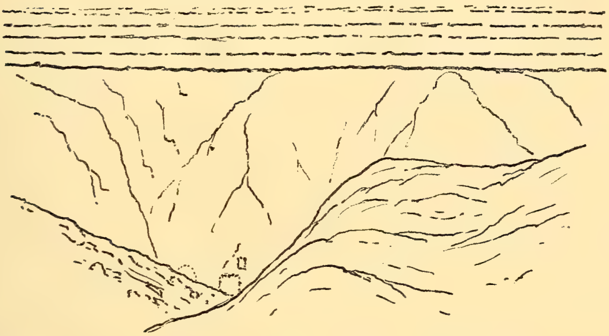
The appended diagram, fig. 1 (made from the lower part of the Vallon de Valeiglia), rough as it is, may save a long description. The iron-ore is clearly associated with a mass of serpentine, above and below which are thick masses of calc-mica-schist. Over these, which became in one part almost a pure marble, we walked in

[1] Quart. Journ. Geol. Soc. vol. xlii (1886) Proc. p. 55, vol. xlv (1889) p. 97, vol. xlix (1893) p. 94, & vol. l (1896) p. 279.

[2] Almost all show the effects of pressure, some to a very great extent. This also frequently spoils junctions. In one instance (in the Tyrol) I suspected a passage, but I should like to examine this again in the light of later experience.

ascending to the mine, crossing, once at least, a little green schist. At the mine itself the mass of ore has been quarried into a cliff (fig. 2), its ends being hidden by spoil-bank; and the greater part, so far as we could see, consisting of a pure magnetite, perhaps 60 feet thick at the middle.[1] It is capped by brownish calc-mica-schist, the junction being very clear and sharp, though inaccessible. In this mass were three or four excavations, the largest, about 20 feet high and 18 feet wide at the entrance, expanding as it descended; but we could not enter it or the next in size, as they were filled with water in which masses of ice were floating. The jointing of the

Fig. 2.—*The Filon Licone.*



[Rough sketch of the magnetite overlain by calc-mica-schist in the quarry-cliff: the height is rather exaggerated in proportion to the breadth.]

1 = Calc-mica-schist; 2 = Magnetite (the dotted lines indicate mines); 3 = Part of an Alp.

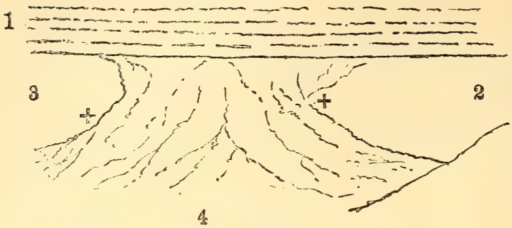
magnetite, both in the cliff-face and in the loose blocks, reminded me of a serpentine; and a slight steatitic film was occasionally perceptible on the brown joint-faces.[2] I then scrambled along the spoil-bank to the more western end of the mass of ore, where it began to disappear beneath the turf. Here I found that the rock consisted of a granular mixture of magnetite and serpentine, which showed some signs of pressure and was slightly veined with a pale yellowish-brown variety of augite (?mussaite). An examination of this part convinced me that the ore and the rock were not sharply divided, but that the one passed, though rather quickly, into the other. About a furlong away in the same direction (the intervening part being masked by débris from above and by turf) a rather similar rock crops out from beneath the calc-mica-schist (fig. 3, p. 58).

[1] M. Parran, Bull. Soc. Géol. France, ser. 3, vol. ii (1874) p. 257, gives the maximum thickness as from 25 to 30 metres, and the length of it as 150 metres.

[2] A few days before, we had seen a heap of blocks near Cogne, and on approaching them were at once struck with the resemblance. On them also we noticed the brown steatitic film.

This on examination proved to be an indubitable serpentine, dark in colour and apt, owing to the effects of pressure, to break up into small pieces.

Fig. 3.—*The Filon Licone.*



[Rough diagram showing the relation of the magnetite and serpentine.]

1 = Calc-mica-schist; 2 = Magnetite; 3 = Serpentine (the positions of specimens described in the paper are indicated thus, +); 4 = Slope of débris and turf: this is greaty contracted, the diagram being intended only to show the unquestionable relation of 2 and 3.

The Filon Larsine is a considerable height up the steep left bank of the Vallon de Grauson: its association with a mass of serpentine is equally clear, and this, which here plunges steeply down towards the torrent, has calc-mica-schists on both sides, the lower mass locally becoming an almost pure marble.[1] The serpentine appeared to me to be a continuation of the one already named; and I find that Cavaliere Jervis says:

'Essa è aperta sopra il prolungamento del giacimento di Licony (*sic*), per cui la sua natura geologica è identica.'[2]

The openings here are at more than one level on the hillside, but we were satisfied with visiting two or three. The magnetite seemed to be as pure as at the Licone mine, but to occur in smaller masses, for the galleries were not so large, and the mixed rock could be found cropping out within a very short distance, in one case actually at the side of the gallery, followed in a few yards by a serpentine, which appeared fairly normal.[3] Here the relation of the magnetite and serpentine was more easily studied, and we had no doubt that the one graduated into the other.[4]

Examination with the microscope confirms the field-evidence. It seemed useless to slice my specimens of the ore, for these appeared on examination with a strong lens to be practically pure magnetite, and the specific gravity of one, determined by a Walker's balance, is 4·64[5]; but I have studied specimens of the serpentine and the

[1] A crag of this had apparently fallen and destroyed the old path.

[2] 'I Tesori sotterranei dell' Italia' pt. i (1873) p. 93.

[3] There was plenty of serpentine and mixed rock in the spoil-bank of the hillside.

[4] It may be worth mention that there are two outcrops of serpentine close to the torrent in the Vallon de Grauson, which are probably a continuation of the same mass, and the higher one seems very ferruginous. The calc-mica-schists are also visible, and lower down the valley, near some chalets named Monro, is an outcrop of quartz-schist, very like that which I have seen associated with the former rock in many other parts of the Alps.

[5] It is a difficult specimen to work with, and I am not quite satisfied with this result. A small chip (not from it) weighed by Mr. Elsden, of University College, London, at the kind request of Prof. Sir William Ramsay, gave sp. gr. = 4·6088. This specimen, however, contained a few steatitic spots.

mixed rock from both mines. It may be convenient, before describing them, to recapitulate briefly the general characters of the Alpine serpentines, which I have examined at not a few localities from Monte Viso to the Gross Glockner, and of which I have at least thirty slices in my own cabinet. Though all are some shade of dark green in colour (I cannot remember to have seen a really red specimen), we can distinguish at least three types:—One dark and compact, probably an altered dunite, not, I think, very common. Another with crystals of bastite and more or less augite—not unlike the dark serpentine on the south side of Kennack Cove (the Lizard): this also is not very common, and rather sporadic in distribution, for I have obtained it on the Col de Sestrières, on the west side of the Julier Pass, near Davos, and in one or two other localities. The third type is rather rougher to the touch, and tougher under the hammer, not porphyritic, but somewhat granular in structure. This is found on microscopic examination to be rather rich in augite, and is abundant about the head-waters of the Visp, as well as to the west, and for a considerable distance to the south, including the Cogne district. All three types are occasionally but little affected by pressure, though in the majority it has developed either an elongated, slickensided phacoidal, or a fissile structure, owing to which the rock breaks into slabs, like roofing-tiles, or even slates, exfoliated pieces being sometimes hardly thicker than a visiting-card. This slaty variety, so far as I can tell—obviously it is not easy to be sure—may be produced from the augitic type, though that mineral has entirely disappeared, and the rock under the microscope consists of more or less filmy flakes of mineral serpentine arranged in a generally parallel order, with lines or very elongated patches of magnetite-granules. We meet occasionally with flakes showing oblique extinction, and the more pressure-modified specimens often show high polarization-tints, but I cannot ascertain that the variety antigorite has any direct connexion with the alteration of augite. Where the latter mineral has been abundant, the commoner type of the (mineral) serpentine appears to be one with a general resemblance to a mica, which gives low polarization-tints, as we shall see in the rocks about to be described.

The specimens of ordinary serpentine collected, as already mentioned, at each mine, prove on microscopic examination to be mainly composed of two minerals: one in transparent flakes, sometimes prismatic, but with less conspicuous cleavage than a mica, which give straight extinction and low polarization-tints—a milky white or occasionally yellow; the other, magnetite,[1] in granules and small grains, occurring often in streaky clouds and occasionally in clusters, when they sometimes form a matrix for the first mineral, like augite does for felspar in an ophitic dolerite. The specimen from the Filon Licone is slightly ferrite-stained and contains some associated granules of residual augite in one part; possibly also a trace or two of bastite. In that from the Filon

[1] In these Alpine rocks the ferriferous grains are almost always opaque. I have rarely met with picotite or a similar spinellid.

Larsine the magnetite (rarely ferrite-stained) sometimes forms little patches, also pierced by flakes, which occasionally give fairly bright polarization-tints, and a slightly oblique extinction (measurement is difficult), and thus are probably actinolite. The specific gravity of the one rock is 2·49, of the other 2·54 : both a little light for an average serpentine, which, however, is probably due to their cracked condition.

The 'intermediate' specimen, from the edge of the mass at the Filon Licone, consists also of serpentine and magnetite, but the flakes of the former are sometimes rather larger than those above described, though occasionally little patches occur, composed of exceedingly minute fibres, thus appearing almost isotropic. The possibly actinolitic mineral is also present, though small in size, and is associated in one place with calcite, perhaps slightly dolomitic. In one part of the slice augite is plentiful in associated grains, separated by minute irregular strings of the ordinary serpentine. The specific gravity of the specimen is 2·77.[1] The other two specimens, from the Filon Larsine, are still more 'intermediate' in character. Both present to the unaided eye a granular structure—serpentine rather irregularly mottled with magnetite : sometimes one, sometimes the other dominating. The specimen broken from the entrance of a gallery and within half a yard, or possibly less, of the pure ore has a specific gravity of 3·54 ; the other one was selected from the 'tip' as a good sample of the intermediate rock, and its specific gravity is 3·73. The microscope shows both these specimens to consist of serpentine (in rather smaller flakes than before, but in the second case with a fair amount of the brighter coloured variety) and of magnetite, more abundant and much of it in bigger grains. Slight indications of pressure are perceptible, but in all other respects the rock bears such a close resemblance to the cumberlandite, so admirably described and figured by Prof. Wadsworth,[2] that it is needless to do more than add another locality to his list.

Two points, however, in these Cogne specimens call for some further notice : the history of the rock and the relation of the magnetite-mass to the normal serpentine. Whether the pressure acted before or after the conversion of the olivine into serpentine is not easily determined. We do not even know the age of the original peridotites. The Alpine serpentines are intrusive in the calc-mica-schists and the green schists (which sometimes, at any rate, are intrusive in the others), and seem to be restricted to the crystalline series.[3] The grains of magnetite in the rock-slices

[1] It would have been easy to have obtained one richer in magnetite, but this was selected because it approached nearer to a normal serpentine and bordered on the augite-vein, mentioned above.

[2] 'Lithological Studies' Mem. Mus. Comp. Zool. Harvard, vol. xi (1884) pl. i, figs. 5 & 6, and pl. ii, figs. 1, 2, & 3. In these the olivine generally remains, but in fig. 6 it is replaced by serpentine. The specimen with some others are described (pp. 75–82), and their specific gravity ranges from 3·55 to 4·06.

[3] There is a possible exception in the Brenner district (Pfons), but I failed to find conclusive evidence as to the relation of the serpentine to the Trias.

have often been more or less fractured; the rough and granular condition of their outer edges suggests aggregation, and they include or are pierced by well-formed prismatic flakes of serpentine; the latter mineral also frequently exhibits a microfoliation. This is equally true of many of the Alpine serpentines in my collection, some of which are actually slaty. But that structure occasionally exhibits marked flexures, so that either the movements have lasted long enough to allow of changes in direction, or there have been two sets. Again, part of the magnetite occurs in minute granules; these may be powdered grains, but, as larger ones also occur, we must not forget the possibility that the smaller may represent the iron-oxide ejected from the olivine during serpentinization. The frequent ophitic relation of the two minerals suggests that either the magnetite was an incoherent powder when the serpentine-flakes were forming, or that there was, after the crushing, a more or less complete reconstitution of the serpentine, which had previously exhibited, as replacing olivine, the ordinary 'network' structure. Beyond this alternative we cannot, I think, proceed, until we obtain further evidence.

Next, how can we account for the presence of these great masses of magnetite in the serpentine? Has the latter been converted into the former by the aid of steam or hot water (pneumatolysis, as it is sometimes called) as a vein of tourmaline-rock is produced in a granite? One of these serpentines generally contains from about 40 to 42 per cent. of silica and 38 to 40 of magnesia, and not more than 10 per cent. of iron-oxides—that is to say (neglecting the water and small quantities of such constituents as alumina and the oxides of titanium, chromium, and nickel, and lime) more than four-fifths of an enormous mass of rock must have been replaced by peroxide of iron.

We must therefore fall back upon differentiation. But how has this acted? Sometimes, as shown by Prof. Vogt,[1] the more basic constituents in a molten mass work towards the exterior or cooler part. There is, however, in the section now visible nothing favourable, and much opposed, to the idea that the magnetite, once disseminated in a molten intrusive mass, has congregated in certain parts of it. So, if this mineral has been separated by differentiation from the original peridotitic magma, that must have been done before the latter reached its present position, or deeper down in the earth's crust. Here the magnetite must have become sufficiently solid to be brought up like huge included fragments in the other material. As the former would still be near its melting temperature[2] some of its outer part might again become liquid and mix with the adjacent magma, both probably being rather viscous: thus producing the intermediate rock. Something of this kind must have happened at Ovifak, where, as is well known, metallic iron not only has been

[1] Zeitschr. für prakt. Geol. vol. i (1893) pp. 4, 125, & 257.

[2] The melting-point of olivine is about 1370° C.; see R. Cusack, Proc. Roy. Irish Acad. ser. 3, vol. iv (1897) p. 412. That of magnetite (*teste* Prof. Joly) varies between 1250° and 1450° C.

brought up in large lumps by the basalt, but also is scattered through it in small grains. In this way I understand Prof. Vogt to explain the presence of the titaniferous magnetite in olivine-hyperite at Taberg,[1] the nickel-silicate in serpentine in New Caledonia and the ores of that metal in other places mentioned in his paper. In processes of mineral separation the residue becomes, sometimes more basic, sometimes more acid, and when separation has taken place on a large scale, either the former may contain fragments of the latter,[2] as in some Scandinavian cases, or, as at Cogne and Ovifak, the reverse may occur. In like way we sometimes find fragments of a granitoid rock in a greenstone, and not seldom of a peridotite in a basalt. Hence, either the heavier rock, as a result of differentiation, must sometimes rise (perhaps in the direction of cooling) sometimes fall (perhaps in consequence of gravitation), or the one rock, whatever it may be, in being squeezed upward or outward from its original position, must be forced through the other. But how and where differentiation has acted, whether by slow separation and concentration in one and the same mass of magma, not long before it began to move upward, or whether in the outer envelope of the originally molten globe, we have no means of determining.

Discussion.

The President said that the Fellows had the pleasure of listening to the Author dealing at one and the same time with two of the subjects which he had made his own—the detailed geology of Alpine regions and the igneous nature of serpentine. As respects the Author's observations and conclusions on this interesting case, they greatly strengthened the theory of those who held that such masses of magnetic iron and the igneous rock now associated with them had a common origin. We ought not, however, in fairness to forget that many, probably the majority, of such masses of iron found associated with basic igneous rocks under somewhat similar conditions to those described, were met with in metamorphic rocks lying, as it were, in the bared roots of greatly compressed and denuded mountain-ranges. There was therefore a simpler hypothesis explanatory of this association: namely, that many of these masses of iron might be merely relics of ancient iron ore-deposits originally of sedimentary origin, or deposited from solution, lying preserved in pinched-in synclines and the like, and which had been intruded upon and partly absorbed by igneous injections of much later geological date.

[1] Zeitschr. für prakt. Geol. vol. i (1893) p. 8.

[2] See summary of Prof. Vogt's work on the iron-ores of Norway and Sweden (by J. J. H. T.), Geol. Mag. 1892, p. 82. [Since this paper was written my attention has been directed to a most valuable and suggestive paper by Prof. Vogt on 'Problems in the Geology of Ore-Deposits,' published, with contributions from Messrs. J. F. Kemp & T. A. Rickard, in Trans. Amer. Inst. Min. Eng. vol. xxxi (1902) p. 125. As I could not obtain a sight of it till this sheet was passing through the press, I can do no more than say that the case at Cogne is not cited, but would not, I think, be really adverse to his views.]

The Rev. E. Hill gave particulars of the difficulty experienced in getting the ore down. So far as he had seen, the ore passed into the serpentine: no junction or divisional line was visible. At the Filon Larsine the serpentine crossed the valley as a dyke. He thought that it was hardly necessary to suppose the ore carried up as a solid body: a viscous material might vary much in composition through its mass.

Prof. Sollas remarked that the explanation of the Author seemed to avoid some of the greater difficulties of Vogt's hypothesis. It was not easy to concede the migration of magnetite-molecules through long horizontal distances in an already ejected and consolidating magma, and a differentiation prior to eruption appeared more likely. The phenomena of Ovifak were more obscure: it was hard to conceive of masses of iron with a specific gravity of 7, some of them weighing 25 tons, being floated up by liquid basalt of specific gravity about 3, unless the molten rock possessed a greater velocity than could be fairly attributed to it. There was, besides, much evidence to suggest that this iron had resulted from the reducing action of carbon upon the basalt, for the latter penetrated carboniferous shales, and in analogous instances in Greenland was found in association with graphite and spinel.

Prof. Watts called attention to the paper of Sir Archibald Geikie & Mr. Teall on the banded gabbros of Skye, in which it was shown that in some cases the iron-ores remained liquid until the other rock-constituents had consolidated. Under these circumstances it was possible that iron-ores might be injected as dykes, in the last stages of consolidation of an igneous magma.

The Author said that he had not attempted to lay down a general theory of iron-ores, but although he was aware that many were of sedimentary origin, the field-evidence which he had described rendered this in his opinion absolutely impossible. Moreover, though he was very well acquainted with the calc-mica-schists, he had never seen anything like a bed of iron-ore in them. He regarded the suggestion advanced by the President as in the highest degree improbable. The point, to which from the first his attention had been directed, was whether the magnetite passed into the serpentine or not. He could not resist the evidence in favour of the former. In reply to Mr. Hill and other speakers, he had in the paper pointed out that the magnetite must have been nearly solid, though apparently it was partly melted at the exterior; but the point which had impressed itself on his mind was that it was carried along like a solid. He thought that the difficulty raised by Prof. Sollas was not really serious, for the peridotite-magma probably was not in a truly fluid but a viscous condition, so that the heavier mass could be moved on as a stone in mud by the lighter. In reply to Prof. Watts, he said that cases of gradual melting down of one rock by another were well known, and though the melting-point of olivine was apparently below that of magnetite, that of other minerals might be higher.

8. GEOLOGICAL NOTES *on the* NORTH-WEST PROVINCES [1] (HIMALAYAN) *of* INDIA. By FRANCIS J. STEPHENS, Esq., F.G.S., A.I.M.M. (Read November 19th, 1902.)

[Abstract.]

'THE country examined extends in a north-westerly direction across the line of strike, from . . . South-eastern Kumaon to north of the Alaknunda River.' The foothills consist of Tertiary clays and sandstones, the snowy ranges of gneissose, granitic, and metamorphic rocks of various descriptions. 'Between the snowy ranges, or rather the more southerly range of the Himalaya chain, a band of hills extends, for nearly 50 miles on an average, to the foothills. The whole area is rich in minerals.' The Author refers to the occurrence of various rocks, met with mainly in this third belt. They include slates with vein-quartz; mica- and graphite-schists; dykes of dolerite; granites; clay-slates, sandstones, and schists, with copper, lead, and tin; limestones, serpentines, and hornblendic rocks, with talc, steatite, etc.; various schists, quartzites, and limestones. The summary of the Author's observations leads him to 'suppose that there are at least three distinct limestone or calcareous series in Kumaon and Garhwal, and that schists and quartzites, with several isolated patches of granitic rock, form a large part of the remaining formations.'

DISCUSSION.

Mr. T. H. HOLLAND remarked that the Author was in error in supposing that the section of the Himalayas within the political limits of the United Provinces had been geologically unexplored. He cited several examples to show that, following M'Clelland and other early workers, various members of the Geological Survey of India had mapped and described large portions of this area, and had, at any rate, gone well beyond the Author's results in classifying the rock-systems exposed. Some of the unsolved problems—as, for example, the correlation of the unfossiliferous rocks of the Outer Himalayas—had not been materially assisted by the present communication, which added no precision to the lithology and did not attack any of the existing stratigraphical difficulties.

[1] [Now officially known as the United Provinces.—ED.]

9. *The* Semna Cataract *or* Rapid *of the* Nile: *a* Study *in* River-Erosion.

By John Ball, Ph.D., A.R.S.M., F.G.S., Assoc.M. Inst.C.E. (Read November 19th, 1902.)

[Plates III & IV.]

Contents.

I. Introductory.

Of the numerous ancient inscriptions discovered in Egypt by Lepsius during his expedition of 1842–1845, few were of a higher degree of interest than those on the rocks at Semna, between the Second and Third Cataracts of the Nile, which record the levels of high Nile in various years under the 12th and 13th dynasties. For, apart from their purely historical value as indicating the importance attached, even at that early age, to precise records of the river which has always been the life-stream of Egypt, these marks serve as a means of gauging the local changes which have taken place through the geological agency of river-erosion during a period of about 4200 years.

Lepsius spent 12 days at Semna and the neighbouring village of Kumna, and besides copying a large number of the inscriptions and making detailed plans of the two temples situated one on each side of the river, he made a sketch-plan of the rapid, and determined the fact that the high-Nile level indicated by the sculptured marks on the rocks is about 24 feet higher than the high Nile of our own day. The data published by Lepsius in his great work [1] were the subject of a careful consideration from the geological standpoint by a former president of the Geological Society, Horner, in 1850.[2] Horner, who does not appear to have himself visited the place, came to the conclusion that

> 'the only hypotheses that could meet the requirements of the facts observed, would be either the wearing away of a reef or barrier at the place in question—a process requiring too long a period—or the existence at some distant period of a dam or barrier, formed perhaps by a landslip of the banks, at some narrow gorge in the river's track below Semna, which in the course of time had again been washed away:—but of the existence of any such contraction of the channel where such a barrier was possible there is as yet no evidence . . . . . The conditions attending these markings, at present so enigmatical, offer an interesting problem to any geologist, well versed in the questions of physical structure involved, who may hereafter visit Nubia.'

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[1] 'Denkmäler aus Ægypten & Æthiopien' Leipzig, 1849–59, Abth. i, Bl. 111–113; Abth. ii, Bl. 139; Abth. iii, Bl. 47–67. See also Lepsius's 'Letters from Egypt' p. 269.

[2] Quart. Journ. Geol. Soc. vol. vi (1850) p. 384. The paper is only published in abstract; I have been unable to consult the original manuscript, so as to examine Horner's reasoning more fully.

Although abundant references to the markings, and the change of level which they indicate, are to be found in historical works published since Horner's day,[1] I have been unable to find that the question has been further investigated by geologists. It was evident that a solution of the problem could be expected only from a further careful examination of the locality; and it was therefore with peculiar satisfaction that I availed myself of the kind permission of Sir William Garstin, the Under-Secretary of State for Public Works, to visit Semna during the Bairam holiday of March 1902, and to publish the results of such examination as I could make there. I was in hope that after a careful survey of the Nile Valley at the place, combined with such data concerning the geology of Nile cataracts as I have been able to pick up during several years' investigation at other points, the enigmatical nature of the marks might disappear. This I believe is really the case; and I hope to show in the present paper that, owing to the structure of the district, a fall in the level of the river at Semna of the magnitude shown by the inscriptions is the natural consequence of such river-erosion as is going on at the present day, acting through the period of 4200 years indicated by the date of the markings.

II. Topographical Description of the District.

Semna is not difficult of access from Wadi Halfa, from which it is about 43 miles distant. The train can be taken as far as Sarras, leaving only about $7\frac{1}{2}$ miles to be covered on camel or donkey, and the road is of a highly interesting character, from the variety of igneous and metamorphic rocks passed through. The route is shown on the Wadi-Halfa sheet (35, I) of the map of the Egyptian Sudan recently published by the War Office.[2] The small hamlet of Kumna, situated within the ruins of an ancient fortress, and inhabited by about 60 poverty-stricken but hospitable Nubians, makes the best halting-place; there are no inhabitants of the ruins of Semna, which lie on the opposite (western) bank.

Immediately above and below the Kumna and Semna temples, the river has a width of about 400 metres (1300 feet), but between the two temples a narrow band of hard red and grey gneiss forms a natural barrier across the stream. At high Nile the river flows over this barrier without any considerable diminution of its width, though, owing to the shallowness of its path and the irregularities of the gneiss-surface, its velocity is much increased and violent eddies are

[1] See, for instance, Prof. Maspero's 'Dawn of Civilization' 4th ed. (1901) p. 488, or Dr. Budge's 'Egypt under the Amenemhats & Hyksos' 1902, p. 46. Dr. Budge states that 'various explanations have been put forward of the extraordinary change which appears to have taken place in the level of the Nile between the time of Amenemhat III and our own, but none of them clears away all the difficulties in the matter.'

[2] I have followed the orthography of this map in the names of the two villages. They are, however, more usually spelled Semneh and Kummeh; and, from a Greek inscription cited by Prof. Maspero, in his 'Dawn of Civilization' 4th ed. (1901) p. 485, it would appear probable that Kum*m*a is a more correct spelling than Kum*n*a.

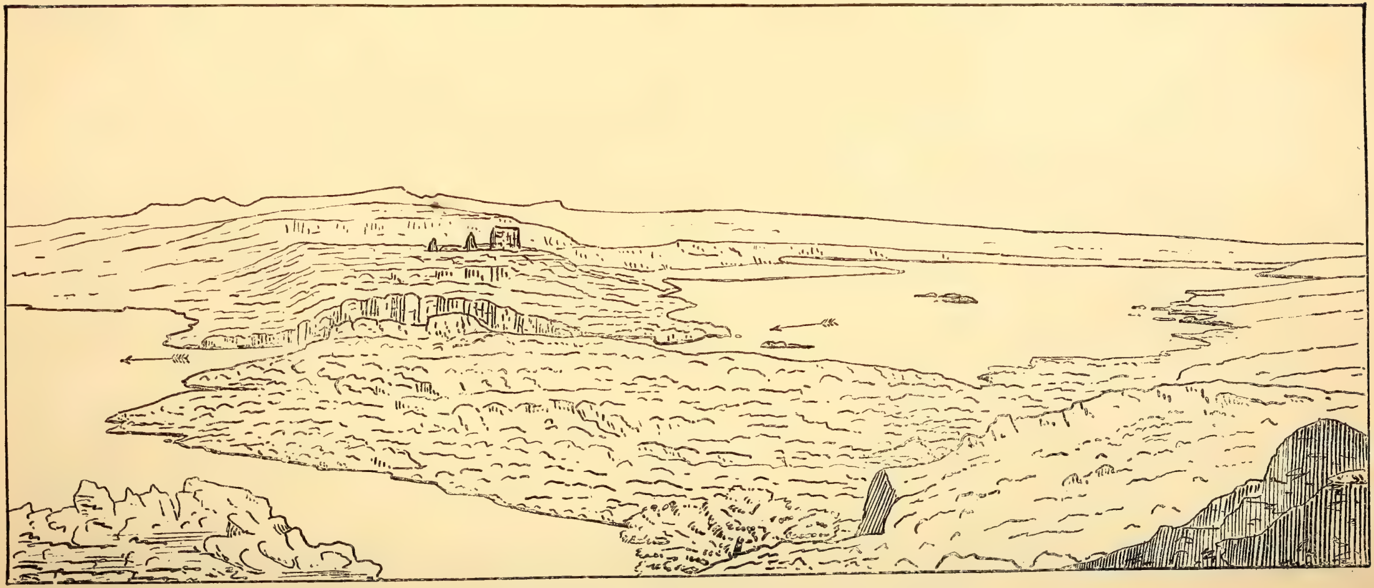
set up. At low Nile the gneiss-band entirely bars the stream, except for a narrow central channel about 40 metres (130 feet) in width.

The accompanying map and section (Pl. III), based on a rapid reconnaissance-survey, represent the condition of things at low Nile in the middle of March 1902. The shore-line and the rocky bar were surveyed with a 3-inch tacheometer; this portion of the map may, I believe, be relied on within the scale-limits. The village of Kumna was measured by pacing, aided by tacheometric fixation of its principal points. The hill-features away from the river, and the brick-ruins of Semna, are only roughly sketched in. Absolute levels were not taken, as this would have involved a long line of spirit-levelling from distant bench-marks. The relative levels shown were found tacheometrically, with untrained fellahîn as staff-holders; they are believed to be accurate to within 0·2 metre (8 inches). The Assuân gauge-reading at the time of the survey was 1 pic 11 kirats, corresponding to the reduced level of 84·93 metres (279 feet), and a discharge past Assuân of 390 cubic metres (13,650 cubic feet) per second. There is so little water taken off between Semna and Assuân, that we may very fairly assume the discharge past the Semna barrier at the time of the survey to be about 400 cubic metres (14,000 cubic feet) per second. The whole of this discharge passed through the 40-metre central channel without any foaming, though the throttling of the entrance by rocky islets produced numerous eddy-currents; and the velocity of the narrow stream, as roughly estimated by the eye, was only about 4 kilometres ($2\frac{1}{2}$ miles) per hour, so that it was at once evident that the channel was deep. A sounding taken in the centre of the rapid gave the depth of water as 23 metres ($75\frac{1}{2}$ feet), but probably 3 metres (10 feet) or so should be taken off, to compensate for deflection of the plumb-line by the current. No soundings were taken outside the central channel; but there doubtless exists a great deepening down-stream of the barrier, due to the action of the water in falling over it. On both sides of the barrier the water was so placid as to resemble a lake more than a river. How great is the contrast between the flow across the bar and that on either side of it, will be evident from the sketch reproduced in fig. 1 (p. 68), which is taken from a photograph.

The ruined temples of Kumna and Semna, with their surrounding forts, lie on elevated portions of the same gneiss-band as that which forms the barrier, and the fissile gneiss has been used by the ancients to form embankments around their erections. The temples, as they now stand, date from the 18th dynasty; but the forts around them are considerably older, and appear to have marked the southern frontier of Egypt proper (not of the Empire) during the 12th and 13th dynasties[1]: thus they formed an appropriate place for registering the height of the flood, which was important as information for the great irrigation-engineers of the time. A large

[1] Maspero's 'Dawn of Civilization' 4th ed. (1901) p. 485; also *id.* 'The Struggle of the Nations' pp. 89, 230.

Fig. 1.—*Rough sketch of the Semna Barrier on the Nile, as seen from the western bank.*



[The arrows show the direction of the stream through the narrow central channel. The ruins of Kumna are seen on the hill beyond the channel.]

number of such records, roughly sculptured on the gneiss-rocks below the temples, are to be seen. I localized and copied several of these on the Kumna side, and am indebted to Prof. Maspero, the Government Director-General of Antiquities, for the translation of the hieroglyphs. One inscription, situated 10·9 metres (36 feet) above the present high-Nile level, reads as follows:—

'Level of the Nile of the year XXIII, under the majesty of King Nimaitra, Son of the Sun, Amenemhat, giving life, stability, wealth, like unto the Sun for ever and ever.'

A group of other inscriptions [1] of different years, in which the same formula is used, are situated just below the Kumna temple at an altitude of 7·9 metres (26 feet) above the present high-Nile level. It should be explained that, although I did not myself see the place when the Nile was in flood, yet there can be no doubt of the correctness of the differences of level noted, as the people of Kumna pointed out the precise spot where they go to get water at high Nile. My observation of the magnitude of the fall of the river between B.C. 2300 and the present day, thus confirms that of Lepsius.

It would appear to be no difficult matter to dam up the river by a filling of heavy blocks in the central channel, but I failed to find any evidence of the former existence of an artificial dam at the place, such as Sir W. Willcocks suggests [2] might have been built by Amenemhat.

III. Geology.

The rocks near the river are igneous and metamorphic for a considerable distance both up- and down-stream of Semna. They consist of granite, diorite, gneiss, and hornblende-schist, with dykes of porphyry and quartzite. West of Semna, at a distance of about a kilometre (5 furlongs) from the Nile, these rocks are overlain by Nubian Sandstone, forming the conspicuous hill called Jebel Barka. On the east side there is no Nubian Sandstone near the river, though Dr. W. F. Hume informs me that it exists farther east than I ventured to wander.

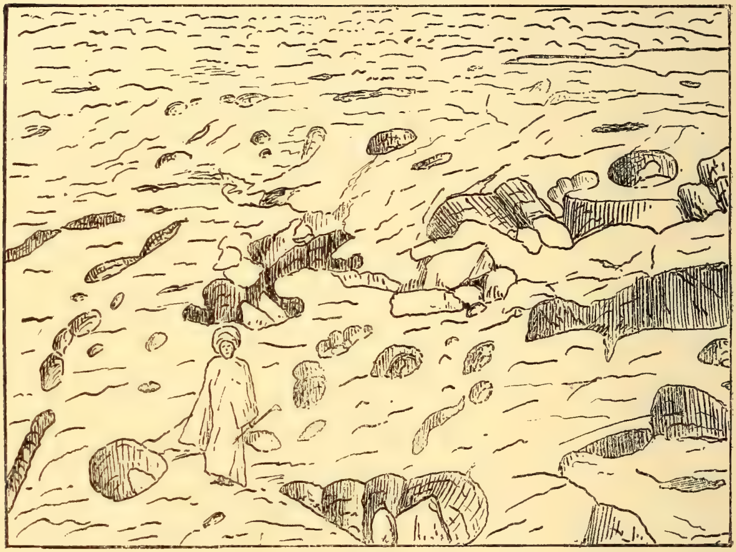
The Gneiss.

The rocky barrier which stretches across the stream between the two temples consists entirely of very hard red and grey gneiss, the foliation-planes of which strike parallel to the direction of the river (that is, north-eastward), and dip about 30° south-eastward. The foliation is extremely marked, the rock being very fissile in spite of its hardness, and the steeply-dipping foliation-planes form slippery slopes polished by the annual dragging over them of the countless tons of sand and silt brought down by the river. The portion of the barrier which is laid bare at low Nile is honeycombed with large potholes (fig. 2, p. 70), which attest the powerful grinding

[1] This group and the preceding inscription correspond, I find, with those figured as K and L respectively in pl. cxxxix of Lepsius's 'Denkmäler' (pt. ii).
[2] 'Egyptian Irrigation' 2nd ed. (1902) p. 30.

action of the stream in flood. Frequently a number of potholes cut one into the other, and masses of rock are thus detached which fall into the cavities and continue the grinding. The rocky bar is of course quite bare of débris, except for the boulders lodged in the numerous potholes and hollows; and even where the rock is untouched by the annual flood, it is of marked freshness, though

Fig. 2.—*Sketch showing potholing of the gneiss-barrier in the Nile, Semna Cataract.*



covered with separated blocks and flakes. Here, as in all arid regions, the process of weathering is mainly one of disintegration without decomposition, the great diurnal variation of temperature being the principal agent in the process. A small amount of chemical decomposition certainly goes on, but its products are removed by water or the sand-blast with great rapidity. The specific gravity of the gneiss is 2·61.

A microscopic examination of the rock shows it to be a highly-crushed biotite-granite, consisting almost entirely of quartz, orthoclase, and biotite, with very minute amounts of apatite, sphene, and iron-oxides. The usual evidences of crushing, in the shape of parallel disposition of the constituents, cracked crystals, cataclastic structure, and undulose extinction, are strongly marked. The variations of colour in the mass are due to variations in the relative abundance of pink orthoclase and dark biotite. The gneiss extends for some distance on either side of the barrier, but here appears to have been more highly crushed, and thus more easily eroded, than the band which forms the barrier itself.

The Syenite-Porphyry.

Dykes of syenite-porphyry are well defined in the gneiss, both on the left bank south of the Semna temple, and on the right bank in the hill behind Kumna. In the latter place the dykes are far from vertical, dipping steeply northward; on the eastern bank they are on gently sloping ground and the dip is not seen, but the strike is about east-south-east. On a fresh fracture, the rock is of an ashen-grey colour with a brownish tinge; it contains in places pink porphyritic crystals of felspar up to 3 millimetres in diameter, in a fine-grained grey groundmass. The exposed surfaces are of a rusty-brown; and where below the high-Nile level they are polished, so as to give the rock the appearance of eisenkiesel. The brown skin penetrates to a depth of about 1 centimetre, the limit between it and the normal grey rock being very sharply defined. The specific gravity of the porphyritic rock is 2·45. Examined microscopically (see Pl. IV, fig. 2), it is seen to consist mainly of felspar (orthoclase), of which there are two generations: the first in large porphyritic crystals, and the second, forming the bulk of the groundmass, in rod-shaped ones. Both classes of felspar are much kaolinized, but they are fresh enough to render their orthoclastic nature evident. There is a considerable amount of hæmatite in large irregular grains, often partly surrounding the felspars of the groundmass; and quartz is sparingly present.

The sections having been purposely cut to show the transition from the grey interior to the brown skin, the explanation of the formation of the latter is readily seen from them. In the internal portions, the hæmatite is in perfectly opaque grains, mostly of considerable size, and there is only a moderate sprinkling of smaller grains, so that the felspars, except for kaolinization, are clear. In the brown skin, the larger iron-oxide grains are translucent, of a red-brown colour; and strings of the same mineral extend through the groundmass between the felspar-crystals in all directions, while at the same time the felspars are themselves full of minute granules and strings of hæmatite and limonite (see Pl. IV, fig. 3). There has thus been brought about by hydrous action a migration of iron-oxides, from the separate clearly defined grains of the normal rock, into the substance of the felspathic groundmass. I am inclined to think that the large opaque hæmatite-grains of the normal rock are a product of oxidation of a ferromagnesian silicate, perhaps biotite. The well-known alteration of biotite with separation of large flakes of iron-oxide is strongly marked in rocks which I have examined from the First Cataract, where it can be seen in every stage. Here, however, not a vestige of biotite or hornblende remains.

The variety of the rock which is free from the pink porphyritic crystals is otherwise exactly the same as the one described, and shows the same process of migration of iron-oxides by water-action. Its specific gravity is, however, slightly higher (2·51).

The syenite-porphyry dykes show less crushing than any of the other igneous rocks near them, and are probably the youngest igneous rocks in the district.

The Hornblende-Schist.

This rock forms a considerable patch on the left bank just above the Semna temple. The relations of this rock to the gneiss are not very clear, but it appears to form a band in the latter. In correspondence with its more basic composition, it is much more highly weathered than the gneiss, and forms a less prominent feature in the landscape. Its specific gravity is 2·96. Like the gneiss, this rock also proves on microscopic examination to be a deformed igneous rock, being in fact a somewhat crushed fine-grained diorite. Hornblende, the most abundant constituent, occurs in highly pleochroic, allotriomorphic crystals (pale yellow to deep blue-green, extinction-angle $\mathfrak{c}-c=18°$). The felspars, which with the hornblende make up the bulk of the rock, appear to lie between andesine and labradorite, sections perpendicular to the brachypinacoid giving extinctions up to 25°. Very small amounts of quartz, and a brown biotite, the latter intergrown with the hornblende, are present; and there are a few idiomorphic crystals of apatite, as well as grains of hæmatite, epidote, and perhaps sphene. The microscopic slide here shows far less evidence of crushing than in the case of the gneiss: the schistose appearance is only well seen in the rock-mass. Hence it would appear likely that the rock represents an intrusion into the gneiss subsequent to the main crushing operation.

The Augitite.

One of the specimens taken from what was thought in the field to be a more basic development of the 'hornblende-schist' above mentioned, proves on microscopic examination to be an augitite of an interesting character. The rock, which is very fine-grained and dense (specific gravity = 3·24), is of a blackish-green in the mass. The thin section shows it to be holocrystalline, and to consist entirely of augite, hornblende, and sphene, with a small amount of interstitial quartz. The augite, which forms about five-sixths of the slide, and of which there is no trace of more than a single generation, is almost colourless, having only a faint brown tinge; it forms a mosaic of more or less rounded granules, with frequent irregular cracks and well-marked cleavages (see Pl. IV, fig. 1). Prismatic sections give extinction-angles up to 42°. Scattered through the augitic mosaic are irregular straggling crystals of green hornblende, and large granules of sphene; these last two occur in about equal abundance. The sphene, though mostly in rounded grains, is sometimes seen in approximately idiomorphic forms, being the only constituent of the rock to appear thus: the grains are about as large as those of the other minerals present, and show strong pleochroism (almost colourless to a rather deep pink-brown). The little quartz present is in the form of small interstitial grains, and is probably of secondary

origin, as the rock shows signs of a certain amount of crushing. Magnetite is entirely absent. The order of crystallization would appear to be (1) sphene, (2) augite, and (3) hornblende, as the last-named mineral frequently occupies interspaces around the augites. Unfortunately, as the exceptional nature of the rock was not recognized in the field, its relations to the associated gneiss and schist were not made out; it appeared, however, to form part of the basic intrusion which has been suggested as the origin of the schist, and thus to be younger than the gneiss.

Physical Geology.

To account for the deep central channel across the bar, I was at first inclined to believe in the existence of a soft basic dyke, such as accounts for most of the channels between the islands of the Assuân Cataract. But I failed to find any evidence of such a dyke, which would in fact have a strike perpendicular to that of the syenite-porphyry veins already mentioned; and I believe this channel, like the parallel smaller channels which are only filled at high Nile, to be due to the simple erosive action of the river, the regularity being due to the coincidence of the direction of flow with the strike of the foliation-planes of the gneiss. It is obvious that at an early stage of the erosion some one channel would be slightly deeper than the rest, owing to accidental circumstances; and this deepest channel, conveying more silt-laden water than the others, would be more rapidly deepened.

The sketch-map published by Lepsius in his 'Denkmäler' (pt. i, sheet 3) was drawn in the latter half of the month of July, when the river would have risen considerably above its lowest level: the true nature of the rocky barrier is thus imperfectly exhibited, and at the same time the extent of the valley shown above and below the barrier was insufficient for a true judgment to be formed as to the manner in which the fall of the river-level had been brought about. From the survey just accomplished at low Nile, it will, I think, be easy to show that the explanation is to be sought in the wearing away of the barrier itself. Horner indeed put this forward as an hypothesis, but dismissed it as requiring too long a period of time. In thus dismissing it he was almost certainly wrong, for the barrier is of small extent, and the yearly removal of a comparatively small amount of it will explain the facts observed. It should be premised that relatively deep water exists both above and below the barrier, which is only about 200 metres (650 feet) in average width; and this condition of things, owing to the difference in hardness of the rocks, must have existed for long ages. Further, the enormous amount of potholing shows that by this means the river is rapidly breaking up the barrier, and that ordinary direct erosion plays a subordinate part.

The area of the barrier is approximately 500×200 or 100,000 square metres. Taking the lowest group of ancient inscriptions of the time of Amenemhat III above mentioned, as marking the average high Nile of the period about 2300 B.C., we have a vertical erosion

of 7·9 metres in 4200 years, or nearly 2 millimetres per year, to account for. Such erosion corresponds to $\frac{2 \times 100,000}{1000}$ or 200 cubic metres of rock, weighing approximately 500 tons, per year.

The amount of rock removed by simple solution in the stream during 4200 years must in itself be considerable; but it is impossible of accurate estimation, and is probably so insignificant in comparison with that removed by mechanical action, that we may neglect it in the following consideration.

The yearly discharge of the Nile past Semna is very nearly 100,000 million tons of water, at a mean velocity of $4\frac{1}{2}$ kilometres per hour at high Nile and $2\frac{1}{4}$ kilometres per hour at low Nile; and it should be remembered that these velocities, which in themselves are capable of accounting for the sweeping along of large pebbles, are locally so much increased by the numerous rocky obstructions as to permit of the movement of boulders and rock-fragments bigger than a man's head. Further, quite apart from the pebbles and boulders which are swept over the barrier and dropped in the deeper water beyond, the quantity of fine silt or rock-flour carried by the stream is certainly not less than 60 million tons per year.[1] And, finally, one must not lose sight of the circumstance, that the strike of the foliation-planes of the gneiss is parallel to the direction of the current, and thus most favourable to the creation of channels across the barrier.

When the foregoing facts are borne in mind, the removal of 500 tons of rock per year under the existing conditions is not only not impossible, but highly probable. Thus such an amount of erosion corresponds to the removal of only $\frac{500 \times 1000,000}{100,000,000,000}$ or 5 milligrammes of rock, per ton of silt-laden water. Or, looking at the matter another way, the potholing action certainly accounts for at least two-thirds of the action, leaving, let us say, 170 tons to be accounted for by the action of the fine silt: this only corresponds to $\frac{170 \times 1000,000}{60,000,000}$ or about 3 grammes of rock per ton of fine silt swept over the barrier.

The rate of erosion demanded by this simple explanation of the facts observed is, moreover, not greater than that which would be suggested by a comparison of measurements of river-erosion made in

[1] The average flow past Assuân is given by Sir W. Willcocks ('Egyptian Irrigation') as 2990 cubic metres per second, or 94,292 million tons per year. At Semna it will, of course, be in excess of this, as some water is taken up by evaporation and irrigation between Semna and Assuân.

The most reliable data as to the amount of silt carried in suspension by the Nile are those obtained by Dr. Mackenzie, Principal of the School of Agriculture at Giza, and published in the Public Works Administration Reports for 1896 (p. 43) & 1898 (p. 101). From the mean of monthly determinations extending over three years, the amount of silt carried past Cairo is 57 parts in 100,000 of water. This gives $\frac{57 \times 100,000,000,000,000}{100,000}$ or 57 million tons per year. Bearing in mind the thick deposits which are thrown down on the lands of Upper Egypt, the quantity of silt passing Semna must be considerably over 60 million tons per year.

other districts. To quote a single well-known case, the River Simeto, flowing through the Etna lava-stream of 1603, had by 1828 cut for itself a passage from 50 to several hundred feet wide, and in some parts from 40 to 50 feet deep.[1] There is doubtless a considerable difference between such lava and the Semna gneiss in point of hardness; but even when due allowance has been made for this fact, the comparison is not unfavourable for the truth of the explanation suggested. Nor can it be objected that the evidence at other points of the Nile Valley is in any way contradictory. It must be borne in mind that, except at the cataracts, the processes of erosion and deposition of silt in the Egyptian portion of the valley of the Nile nearly balance each other; while at the cataracts the action is purely erosive, and in fact corresponds more to that of a mountain-stream than to that of a peacefully-flowing river.

A study of the Semna rapid, which may be taken as the simplest possible case of a Nile cataract, throws considerable light on the study of more complex cases. All the Nile cataracts exist at points where igneous and metamorphic masses crop out through the softer sedimentary rocks, and are the consequence of the greater difficulty which the river finds in eroding a course through such masses. We are still far from having sufficient information, concerning these interesting features of the great Egyptian river, to be able completely to trace its past history as a geological agent; but my own researches at the Assuân Cataract, and those of my colleague Dr. W. F. Hume at the higher ones, have brought to light a number of very striking facts, more especially concerning the influence of dykes and faults in determining the river's course, and there is ground for hope, that when all the observations have been worked out and co-ordinated, a very considerable advance in the study of the problem will have been made. At Assuân and Silsila the river has entirely changed its channel and suffered a considerable lowering[2] within geologically recent times, though before the historical period; and it is probable that such changes were largely brought about by the removal of long pre-existent hard barriers such as the one at Semna. There can be no doubt that at all these cataracts erosion is very rapidly going on, though masked from observation by the absence of records of sufficient antiquity and by the great variations in the floods of different years. At Silsila and at Kalabsha in Lower Nubia, the river passes rapidly through narrow gorges in hard rocks; and when soundings and borings were taken there a few years ago for the proposed reservoir-dams, it was found that the bottom of the stream, far from being, as was expected, solid rock, was in fact in each case composed of sand to a depth of over 20 metres.[3] It is impossible to explain the existence of this thick sand-stratum, unless we assume

[1] Lyell, 'Principles of Geology' 11th ed. (1872) vol. i, pp. 352–53.

[2] My own observations give the fall at Assuân as at least 20 metres (65 feet), while Prof. Schweinfurth gives that at Silsila as 20 to 22 metres, Petermann's Mitth. vol. xlvii (1901) p. 9. If, in these cases, the lowering of the stream has proceeded at a rate similar to that recorded at Semna, the period corresponding to the changes is about 10,000 years.

[3] For this information I am indebted to Mr. Marshall Hewat, who conducted the borings in question for the Egyptian Government.

that there formerly existed barriers at these places, the fall of water over which would cause a great deepening of the channel on the down-stream side, and as the barrier was gradually worn back the local deepening of the channel would become filled with silt.

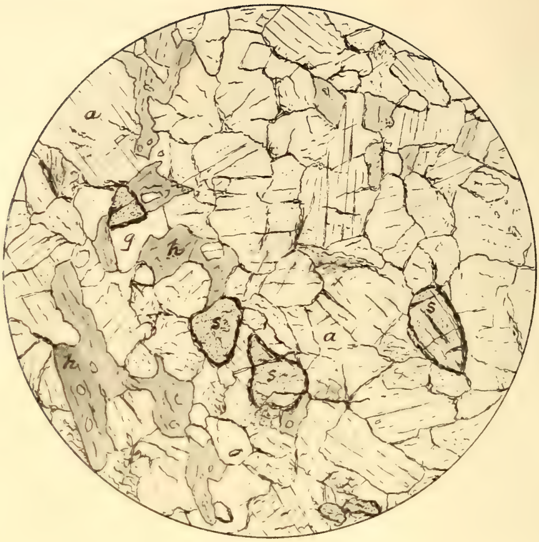
Suprisingly deep soundings have been taken quite recently below the new reservoir-dam at the Assuân Cataract, and these again can only be explained on a like assumption. Thus it would appear that, after allowing for the well-known tendency to gross exaggeration in early 'travellers' tales,' there may have been some foundation for the statements of numerous classical writers,[1] who describe the Assuân Cataract as a distinct waterfall, tumbling over a precipice with a loud noise; more especially if they relied on a tradition handed down from earlier times, rather than on the evidence of an eye-witness of their own day. Finally, the fact that the whole of the cultivated lands of Lower Nubia, and the large alluvial tract which forms the Kom Ombo plain, lie at so great an elevation as to be impossible of irrigation at the present day without the aid of water-raising appliances, is easily explained by the hypothesis that, at Silsila and Assuân at least, the river was formerly dammed back by natural obstructions which have since been eroded away.

A very good site for a quantitative determination of the rate of erosion in granite by the silt-laden waters of the Nile will be furnished by the sluices of the new dam at Assuân. In this case all large stones will be kept out by grids, so that only the smaller pebbles and sand will be carried through, and some years will doubtless have to elapse before the erosion has proceeded sufficiently for a reliable measurement to be obtained. And with regard to the rate at which potholing action is removing the barrier at Semna, it would appear not difficult to make a fairly accurate experimental determination within a few years, for the action is certainly a relatively rapid one, and the holes are laid dry regularly every year at low Nile.[2] It would be easy to mark a few average holes, and after temporarily removing their contents, to measure their transverse dimensions and their depths below artificial datum-marks deeply sculptured in the sides of the holes; if then the stones were replaced within the holes exactly as found, and the action allowed to go on for a few years, a remeasurement would indicate the average

[1] Diodorus Siculus, *Hist.* l. i, c. 3; Strabo, *Geog.* l. xvii, c. 1, § 49; Pomponius Mela, *De situ orbis* lib. 1, c. 9; Seneca, *Nat. Quæst.* l. iv, c. 2.

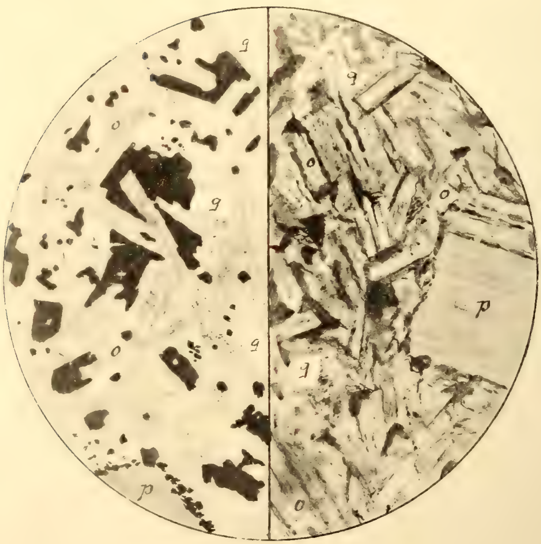
[2] That potholing may, under certain favourable conditions, proceed at such a rate as to permit of easy measurement after a few years' action, is proved by an observation in Sweden, recorded by Axel Erdmann ('Bidrag till Kännedomen om Sveriges qvartära Bildningar' Sver. geol. Undersökn. ser. C, No. 1, 1868, p. 82). About 1858, when the Oena paper-mills were built on the western bank of the Göta Elf, near the falls of Trollhättan, the required water for driving the mills was conducted from the river through a channel, which was at the time blasted entirely out of the rock. When an extension of the mills took place some 8 or 9 years later, it became necessary to widen this channel, for which purpose the water was drained off. It was then found that three small potholes had been formed in the bottom of the channel, of a maximum depth of $1\frac{1}{2}$ feet, and of diameters varying from 6 to 12 inches, with the rounded pebbles (of trap) still remaining within them. Thus 8 or 9 years had been a sufficient time for the formation of these potholes, through the rotating motion given to the stones by the water flowing through the channel.

I.



X 45.

II. III.



X 40.

Augitite and Syenite-Porphyry from Semna.

J. Ball, del. *Bemrose Ltd., Collo.*

rate of enlargement. Then, by roughly counting the holes and multiplying, a very fair idea of the total amount of rock removed per year by such action would be obtained. I trust later on to find an opportunity of making such observations, time for which failed on my last visit, and thus to confirm or otherwise the view which I have expressed above,—that the lowering of the high-Nile level observed between B.C. 2300 and the present day, is a simple consequence of the operation, through the period of 4200 years, of that erosive action which is going on in our own times.

EXPLANATION OF THE PLATES.

Plate III.

Map and section of the Nile Valley at the Semna Cataract on the scale of $\frac{1}{4000}$.
[The distance to Sarras on the map is misprinted as '72' instead of 12 kilometres, or $7\frac{1}{2}$ miles.]

Plate IV.

Fig. 1. Augitite from Semna, × 45. *a*, augite; *h*, hornblende; *s*, sphene; *q*, interstitial quartz. (See p. 72.)
2. Syenite-porphyry from Semna, normal form of the rock, × 40. *p*=portion of a porphyritic orthoclase-crystal, with peripheral hæmatite-grains; *o*=orthoclase of groundmass; *q*=quartz; the dark masses are hæmatite, perhaps an alteration-product of biotite. (See p. 71.)
3. The same rock: outer crust, showing redistribution of iron-oxides, × 40. The minerals bear the same letters as in fig. 2.

Discussion.

Sir Archibald Geikie remarked on the value of observations which in any degree helped to furnish numerical measurements of the rate of geological changes. The data supplied by the Author appeared to be trustworthy, and to justify the inference which he drew from them. They showed a comparatively rapid erosion at that particular contracted part of the Nile. Though it might not be safe to conclude that the conditions of this erosion had been for a long time as they are now, it was at least an important point to obtain an average rate of denudation during so long a period as that which seemed to be indicated by the ancient Egyptian marks of water-level.

Prof. Sollas remarked that this was an interesting contribution to the history of the Nile Valley, and that the measurements made by the Author would afford useful data for subsequent observers. While evidence was obtained of the total erosion produced during a given period, no conclusions could be drawn as to a yearly rate, unless it were assumed that both the volume of the Nile and the slope of its channel had remained constant for the past 4000 years. It would be of interest to know whether the ancient records referred to an average, or to an unusual, high Nile.

Prof. Hull thought that the Author's observations would have been of more value if he had taken into consideration the changes in the physical conditions of the Nile Valley which may have had influence upon the rate of erosion at the Cataract. No problem of this kind could be solved without recognizing the former much

larger volume of the river, and the submergence of the Nile Valley to the extent of 200 feet below its present level, as shown by the raised beach at Mokattam above Cairo.

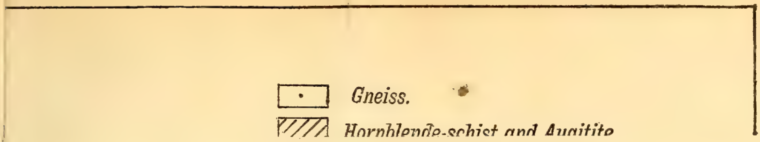
Mr. Marr asked whether there was any mention of joints in the paper. In an ordinary flowing river, the rock on the sides of joints passing from bank to bank could not be eroded more rapidly than the rock down stream, but in the case of waterfalls this was changed. Erosion was much more rapid along the joint-planes than along the intervening solid rock, and thus waterfalls usually bifurcated or split into even more numerous branches. As erosion proceeded along the dominant joints, the minor fissures became channels in wet weather only, and were at last deserted by the stream, so that ultimately the stream was confined to a channel along a dominant joint-plane, producing an effect such as that shown in the Author's plan. It must, therefore, be borne in mind that other factors than increased velocity of stream, as for instance the excessive erosion along joint-planes, must be taken into account in comparing the rate of erosion at falls with that in ordinary parts of a river's course.

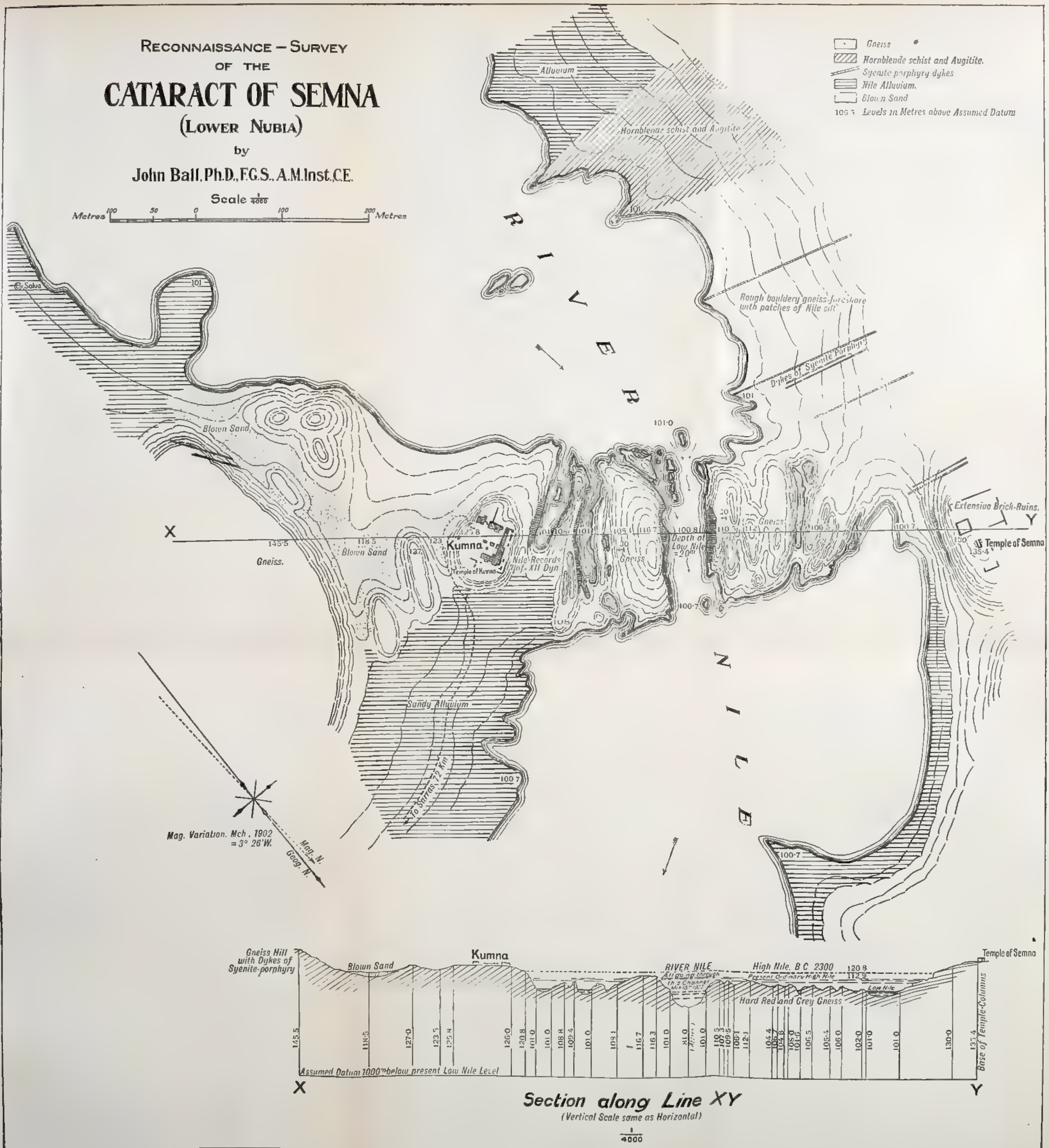
Prof. Groom asked whether there was any evidence that tectonic movements had had an effect on the conformation of this part of the Nile Valley, and whether some of the differences in the depth of particular parts of the channel might not be due to this cause.

Prof. Judd (in the absence of the Author) thanked the Society for the kind manner in which they had received the paper. He felt sure that it would be a great encouragement and incentive to future work, both to the Author and to his colleagues upon the Geological Survey of Egypt. In reply to Mr. Marr he stated that the Author found in the foliation, rather than in the jointing of the rock, those points of weakness that were favourable to excessive 'pot-holing' and erosion. The speaker recalled the papers on the subject published by the Society during the early years of its history, and stated that shortly before Sir Charles Lyell's death, he had visited with the veteran geologist the places where mason's marks had been made by Sir Charles when quite young, in the hope of determining the amount of erosion by rivers. Considerable erosion had taken place in the course of fifty years, but the mason's marks were not altogether obliterated.

Postscript to Discussion.

[In reply to Prof. Sollas, the Author observes that there are a large number of high-Nile marks dated in the different years of Amenemhat's reign, and the inscription selected in the calculation of the erosion is one of the lowest of them; so that it may be taken to represent fairly an average, and not an exceptional, high Nile of the period. Although it is certain that the volume of the Nile was formerly greater than at present, there is no evidence that any very considerable change of volume has taken place within historical times. The changes at Assuân and Silsila are proved, by the positions of numerous inscriptions, to have occurred before the dynastic period; and though the river is of course gradually


Gneiss.
Hornblende-schist and Augitite


Reconnaissance – Survey
of the
CATARACT OF SEMNA
(Lower Nubia)
by
John Ball, Ph.D., F.G.S., A.M.Inst.C.E.
Scale 1/4000
Metres 100 50 0 100 200 Metres
Gneiss
Hornblende schist and Augitite.
Syenite porphyry dykes
Nile Alluvium.
Blown Sand
106·3 Levels in Metres above Assumed Datum
Alluvium
Hornblende schist and Augitite
River Nile
Rough bouldery gneiss-foreshore with patches of Nile silt
Dykes of Syenite Porphyry
Blown Sand
Extensive Brick-Ruins.
Temple of Semna
Kumna
Temple of Kumna
Nile Records of XII Dyn
Depth at Low Nile =20m
Gneiss.
Sandy Alluvium
To Sarras 72 Km
Mag. Variation. Mch. 1902 = 3° 26' W.
Mag. N.
Geog. N.
X
Y
Gneiss Hill with Dykes of Syenite-porphyry
Blown Sand
Kumna
RIVER NILE
High Nile. B.C. 2300
Present Ordinary High Nile
Low Nile
Hard Red and Grey Gneiss
Base of Temple-Columns
Temple of Semna
Assumed Datum 1000m below present Low Nile Level
Section along Line XY
(Vertical Scale same as Horizontal)
1/4000

flattening the inclination of its channel, the situations of numerous temples along its course are such as to prove the change to be a very slow one. Moreover, the rapid of Semna lies between the Second and Third Cataracts, where a similar, though perhaps slower, erosion is going on; and the average inclination of the river between them would remain constant if, as is probable, the rates of erosion at the upper and lower cataracts were approximately equal. Thus, while it is not possible to assert that the volume and inclination of the stream have remained constant for 4000 years, there is a strong probability that the change in these factors has been comparatively small in the given time.

The submersion of the lower part of the Nile Valley, as shown by raised beaches above Cairo, is, as Prof. Hull remarks, of very great importance in any consideration of the early history of the river. But the fact of the existence of the city of Memphis (the ruins of which are still to be seen near Cairo) for over a thousand years before Amenemhat's time, is sufficient to prove that the deposits referred to long antedate the historical period, and thus they indicate nothing as bearing on the question of erosion within the last 4000 years.

With respect to the question raised by Mr. Marr, I would only add to what has been stated in the paper, that in the minor channels, left dry at the time of my visit, I saw but little evidence of joints cutting across the foliation-planes; and thus, although it is quite possible that the position of the main channel may have been primarily determined by a joint or fissure, I was led to conclude that it, like the others, was conditioned simply by the foliation-planes, which themselves are planes of weakness. Joints and crush-planes perpendicular to the foliation-planes are of great frequency in the gneisses and schists immediately above Assuân, where they account for most of the 'khors' or side-valleys opening to the river; but they are less abundant near Semna, and, as I have said, not evident at all in the rocky barrier itself.

With regard to Prof. Groom's question concerning tectonic movements, it is certain that large portions of the Nile Valley have been subjected to such changes. But a great deal of work remains to be done before the nature and extent of such movements can be even approximately determined; all the evidences that I have yet been able to examine tend to show that the tectonic movements, like the climatic changes, ceased long before the historical period with which my paper is more immediately concerned.

Thus I consider that the change which has undoubtedly taken place at Semna within the last 4200 years cannot be explained as due to any change in the discharge or general inclination of the river, nor to fissures, nor to tectonic movements, nor, in fact, to anything but simple erosion at a very rapid rate owing to the local contraction of its channel.—J. B., *December 9th, 1902.*]

10. *The* ELK (*ALCES MACHLIS*, OGILBY) *in the* THAMES VALLEY. By EDWIN TULLEY NEWTON, Esq., F.R.S., F.G.S. (Read December 17th, 1902.)[1]

[PLATE V.]

THAT the elk, *Alces machlis*, was an inhabitant of Great Britain in prehistoric times is now an established fact. Sir Richard Owen, in 1846, did not obtain satisfactory evidence of the elk as a British fossil, and consequently the genus is not included among his 'British Fossil Mammals' published at that date: writing, however, in 1869,[2] he accepted the recorded discovery of elk-remains in a peaty bed in Northumberland, and himself described certain bones of the same species from a similar peaty deposit at Walthamstow, Essex. In the light of more recent discoveries, it seems likely that some of the earlier accounts of the discovery of elk-remains, which had been discredited, were really founded on bones or antlers of *Alces machlis*, and were not, as had been thought possible, due to a wrong determination of the specimens, or to the misuse of the name 'elk.' However that may be, numerous reliable accounts have since been published, which have established the occurrence of the true elk (*Alces machlis*) in a semifossil state at numerous localities in both England and Scotland. Two specimens referable to *Alces machlis* are said to have been found in Ireland. One is a skull with antlers, preserved in the Belfast Museum; but Leith Adams,[3] having specially examined this skull, came to the conclusion that it was of recent origin and had been imported into Ireland. The second specimen was mentioned by Hermann von Meyer[4] in 1832. He gave a figure of an undoubted elk-antler, said to be from Ireland, preserved in the Museum at Leyden. Unfortunately, its precise locality and horizon are unknown.

A full account of the discoveries of elk-remains in the British Isles previous to the year 1872 is given by John Alexander Smith,[5] who mentions more than twenty localities where such remains have been found, extending from Sutherland to Essex. The greater number of these records are from the southern parts of Scotland and the northern parts of England: the southernmost locality being Walthamstow in Essex, recorded by Owen (*loc. cit.*) in 1869. The specimens described by Owen from Walthamstow I have examined in the Natural History Museum, and see no reason for doubting the identification.

In the year 1863 Édouard Lartet[6] saw in the Oxford University

[1] Communicated by permission of the Director of H.M. Geological Survey.
[2] Geol. Mag. vol. vi (1869) p. 389.
[3] Journ. Roy. Geol. Soc. Irel. n. s. vol. iv (1877) p. 248.
[4] Nova Acta Acad. Cæs. Leop.-Car. vol. xvi (1832) p. 471.
[5] Proc. Soc. Antiq. Scot. vol. ix (1872) p. 297.
[6] 'Revue Archéologique' n. s. vol. ix (1864) p. 250, footnote.

Museum some mammalian remains from a cave at 'Lhandebie,' in Caermarthenshire, among which was a cervine jaw which he referred to elk ('un maxillaire d'élan'). This determination was given by J. A. Smith[1] as evidence of the elk in South Wales; but Prof. W. Boyd Dawkins[2] says that the specimen, which he saw in the Oxford University Museum, is referable to the Irish *Megaceros*, and not to the genus *Alces*. Up to the present I have not been able to see the specimen, and accept Prof. Dawkins's correction.

There is in the Natural History Museum at South Kensington the left frontal and antler of *Alces machlis* (M. 3824), said to be from Cleveland (Yorkshire), which was presented to the Museum by the Trustees of the Christy Collection, in 1889. It appears that the specimen was originally in the possession of the late Mr. Edward Tindall, of Bridlington. Mr. Thomas Boynton, of Bridlington, who knew Mr. Tindall and is much interested in the remains of fossil elk, believes this specimen to be the one obtained by Mr. Tindall[3] from a lacustrine or peaty deposit on Carnaby Moor; and in kindly answering my enquiries, says he thinks that some mistake has crept in as to the locality on the label. He also says that he himself possesses an antler of *Alces machlis*, found about 60 years ago at Barmston, about a mile from Carnaby, in a similar lacustrine deposit. It is not deemed necessary to allude specially to other known specimens of fossil elk, as the references will be found in the works noticed on pp. 88–89.

I am now able to make known an interesting discovery of elk-bones near Staines, on the River Thames. My colleague Mr. T. I. Pocock, working in the district, found that some mammalian remains had been discovered during the construction of the Staines Reservoir, and wished them to be examined for the purposes of the Geological Survey. By the Director's desire I examined these remains, which included a skull with a pair of antlers undoubtedly belonging to the elk, *Alces machlis*; the range of which southward as far as the Thames, was thus fully confirmed. It appears that some three or four years ago, in connection with the construction of the large reservoirs at Staines, an aqueduct was built leading from the Thames, and at about 6 furlongs north-west of Staines the excavations for this aqueduct were carried across the Wraysbury River. Mr. W. B. Duff, the resident engineer, to whom we are indebted for all the particulars of this discovery, has kindly given me the following information. It was at Youveney, on the right bank of the Wraysbury River, as it runs at the present time, and at a depth of 7 feet below the surface, in a somewhat peaty soil, that the antlers and bones were found. It appears that when this part of the Great Western Line was constructed some years ago, the Wraysbury River was diverted from its old bed, which is about 100 feet to the south-west of its present course and of the place where the elk-bones

[1] Proc. Soc. Antiq. Scot. vol. ix (1872) p. 339.
[2] 'British Pleistocene Cervidæ' Monogr. Palæont. Soc. 1886 (1887).
[3] See Proc. Yorks. Geol. & Polytechn. Soc. vol. v (1870) p. 7.

were found. Mr. Duff suggests the possibility of this ground having been disturbed when the new course for the river was dug; but it seems very unlikely that the bones were disturbed at that time, for if they had been, they would almost certainly have been more broken than they are. It is more probable that the bones have lain undisturbed in the peaty mud of the marshy river-bank, until they were unearthed some three or four years ago.

It is by the courtesy of the engineers for the Staines Reservoirs, Messrs. Walter Hunter & R. E. Middleton, that I have had the opportunity of examining these interesting fossil-remains, which included, besides the elk-skull and antlers already mentioned, a pair of lower-jaw rami with complete set of grinding-teeth and a tibia, which almost certainly belonged to the same animal. With these elk-remains were portions of other cervine mammals: namely, a lower-jaw ramus and a tibia of a large red-deer (*Cervus elaphus*) and an antler of a fallow-deer (*Cervus dama*). Besides these, were found the skull and lower jaw of a pig (*Sus scrofa*), the teeth of which were worn away almost to the roots, and the lower jaw much diseased; and, lastly, there were a skull and a metatarsal of a horse.

Description of Elk-Remains.

Antlers and brain-case.—The right antler and the brain-case are almost perfect, but the left antler is somewhat broken, and the anterior facial parts of the skull, together with the maxillaries and upper teeth, are wanting. The frontal suture not being closed has given way, so that the left frontal bone with its antler is detached from the rest of the skull. The two antlers are not quite alike in form, and the right one is larger than the left; but both are widely palmated, and show little or no indication of the division into anterior and posterior portions such as may mostly be seen in modern elk-antlers. The pedicles with the beams extend almost directly outward from the frontals, with a curve downward and forward. There is no indication of a brow-tine. When the base of the skull is horizontal, the concave surface of the palmation looks almost directly upward. The right antler, which is the most perfect, has had six (or perhaps seven) points. The frontal bones between the antlers are raised into a rounded, but well-marked crest, which is seen in both front and side views, and stands higher than antler-burrs. Immediately in front of this crest, and just behind the level of the orbits, is a large median depression divided by a slight ridge along the frontal suture. The following are some of the most important measurements:—Circumference of right pedicle$=6\frac{1}{2}$ inches (163 millimetres); from frontal suture to outermost tine (imperfect) of right antler$=21$ inches (535 mm.). Same measurement of left antler$=19$ inches (475 mm.). The greatest width across both antlers to outermost tines$=39$ inches (985 mm.). Width of palm of right antler, measured from tips of anterior and

posterior tines as now preserved = about 18 inches (457 mm.); but when perfect it must have been $22\frac{1}{2}$ inches (560 mm.) wide. Length of beam from burr to beginning of palmation = about 5 inches (120 mm.). Least distance between two burrs = 8 inches (202 mm.). Greatest width of skull at hinder and outer margin of orbits = $8\frac{3}{4}$ inches (223 mm.).

The form of this skull; the palmation of the antlers; the outward direction of these from the frontals; as well as the absence of any brow-tine, are characters which prove this specimen to have belonged to the elk (*Alces machlis*).

Lower jaw.—The pair of rami found with the skull and antlers undoubtedly belong to an adult elk, and almost certainly are parts of the same animal as the skull and antlers just described. A comparison of these rami with several jaws of elk in the Museum of the Royal College of Surgeons leaves no doubt as to their specific identity. The description of the left ramus, which will now be given, would do equally well for the ramus of one of the specimens of *Alces machlis*; such small differences as exist will be pointed out in the course of the description.

The jaw is cervine in character, and led me in the first instance to compare it with the great Irish deer (*Cervus giganteus*); but obvious differences are at once seen, which prevent its reference to that animal.

The great length of this ramus is very striking, and this peculiarity is especially marked in the region of the diastema; the distance between the anterior premolar tooth and the alveolus for the outermost incisor is 6 inches (153 mm.), and must have been more than 7 inches (175 mm.) when perfect. In the region of the cheek-teeth the ramus is flattened from side to side, more compressed indeed than in either of the rami of recent elks with which it has been compared. The length of the ramus, $19\frac{1}{4}$ inches (480 mm.), is greater than in either of the recent specimens; while the six cheek-teeth occupy rather less space than the teeth of those specimens.

The molar teeth differ in pattern from the premolars, but all have short crowns and coarse enamel. On the outer side the anterior true molar has a large tubercle at the base between the two lobes, while the second and third true molars only show a very small tubercle in this position. In three recent male elks this tubercle is only seen in the first true molar; but the lower jaw of a female has it well developed in all three true molars. In the great Irish deer (*Cervus giganteus*) this tubercle is large in all the true molars.

The premolar teeth are proportionately large: the hindermost one having as great an antero-posterior extent as the first true molar; and the enamelled crown is absolutely higher than in that tooth. This same hindermost premolar has the outer surface divided into two distinct lobes—the anterior larger than the posterior lobe, and separated, the one from the other, by a deep groove,

which extends to the base of the enamel; this last-named character at once distinguishing this fourth premolar from that of *Cervus giganteus*. The greater height of the crown of this tooth causes the edge of its alveolus to be pressed down below the level of those of the true molars, and results in an uneven alveolar margin, which is rendered more obvious by the base of the anterior premolar being somewhat above the line of the true molars. Another character of the hindermost premolar is seen in the pattern of the grinding-surface; two deep sulci extend obliquely quite across the tooth, from behind forward and outward, dividing the surface of the crown into three unequal portions. When a little more worn, the anterior and larger sulcus would become closed in front; indeed, this closure has taken place in the corresponding tooth of the right ramus. The extension of the oblique sulci quite across the tooth is unlike what is found in *Megaceros*, where these sulci are very shallow, and consequently are early cut off from the outside by the wearing of the tooth, giving a very different aspect to the pattern of the grinding-surface. It is worthy of note that this peculiarity of the fourth premolar agrees very closely with what is found in the corresponding tooth of the reindeer.

Another peculiarity of the elk's teeth is the extreme obliquity of the crescents as seen on the grinding-surface: this character is well shown in the lower jaw of the Staines specimen. The inner and hinder part of each crescent projects inward much beyond the anterior part of the crescent next behind it, thus giving a strongly serrated edge to the inner surface of the lower cheek-teeth. In the Irish *Megaceros* this obliquity of the crescent is much less, and the serration nothing like so prominent.

Besides the differences above mentioned, the lower-jaw ramus of *Megaceros* differs from the Staines specimen and the recent elk in being much thicker below the cheek-teeth; in having a less elevated articular and coronoid process; and in the diastema being much shorter.

As already stated, there can be no question as to these rami from Staines being referable to the true elk (*Alces machlis*), and not to the Irish *Megaceros* (*Cervus giganteus*).

Measurements of the Lower Jaw.

	Millimetres.
Coronoid process to alveolus of median incisor	490
Articular condyle to ditto	465
Angle to ditto	440
Depth of ramus on inside below hinder end of m. 3	64
Do. do. do. in front of anterior pm.	52
Thickness of ramus below m. 3	28
Length of alveolar margin of cheek-teeth	165
Do. three premolars	73
Do. three molars	95
Do. grinding-surface of pm. 4	27·5
Do. grinding-surface of m. 1	28·0
Height of enamel-crown, outside pm. 4	25·0
Do. do. do. outside m. 1	19·5
Distance between front pm. and alveolus of outer incisor	153·0

Tibia.—The tibia found with the skull and lower jaw, which is likewise referred to *Alces machlis*, is remarkable for its great length and slenderness: for, while equalling in length the tibia of a large *Megaceros*, its proportions are those of the red deer rather than those of *Megaceros*, the limb-bones of which, it will be remembered, are almost bovine in their stoutness and general proportions. The limb-bones of the modern elk are characterized by similarly slender proportions; indeed, the comparison of a tibia with the one from Staines leaves no room for doubt as to their identity. The following measurements of three tibiæ indicate these proportions, but do not make them so obvious as an examination of the specimens themselves:—

Measurements of Cervine Tibiæ.

	Staines specimen.	Modern Elk.	*Megaceros.*
	Millimetres.	Millimetres.	Millimetres.
Greatest length	515	495	500
Width of proximal end	103	114	127
Width of distal end	71·5	70	86
Least circumference of shaft	129	114	156

Age of Deposits in which *Alces machlis* has been found in Britain.

The elk-remains hitherto found in Great Britain have mostly occurred in peaty ground, or in near relation with peat; but the evidence for the age of the deposit has been in many cases very unsatisfactory. Only in a few instances have any other remains been found, with those of the elk, which might indicate the age of the deposit. In no case, so far as I can ascertain, have elk-remains been found in a definitely Pleistocene deposit, or associated with positively Pleistocene mammals. In a few instances, red deer, roedeer, or *Bos primigenius* have been recorded as accompanying the elk-bones; and at Walthamstow, the deposit yielding the elk also contained implements of the Bronze and Celtic ages, together with beaver, reindeer, *Bos longifrons*, *Bos primigenius*, and a number of modern species. Although *Bos primigenius* is a Pleistocene form, it is known to have lived in Europe in Roman times: any deposit, therefore, in which its remains may be found is not necessarily older than that period.

The assemblage of remains found at Walthamstow would seem to limit the age of the deposit yielding the elk to some period between the Neolithic and Celtic times, for *Bos longifrons* is not known from deposits earlier than Neolithic. Some confirmation of this limit is found in the fact that in the bed immediately below

the one containing the elk, remains of *Elephas primigenius* were discovered.

The elk-remains found at North Berwick [1] are said to have been accompanied by Roman objects, which, if correct, would point to the elk having continued in Britain until the Roman period, which is not improbable, seeing that it is known to have been living in Central Europe in Cæsar's time.

It is a remarkable fact that, although *Cervus giganteus* and *Alces machlis* have been found in similar peaty deposits in the United Kingdom, their remains do not seem ever to have been found together. *Megaceros* was certainly contemporaneous with the mammoth, and continued to inhabit Great Britain and Ireland while some of our peat-deposits were being formed. The elk, as we have seen, is not known as a Pleistocene mammal in this country, but appears for the first time in more modern peaty deposits. Both these large cervine mammals have been recorded from the Isle of Man, but not as being found together.

Although the occurrence of remains of these two animals in peat would seem to show that both were living here at about the same period, yet, as the formation of peat has continued for a lengthened period, the particular peat-beds in which these two animals have left their remains may be of different ages, and the elk may not have arrived here until after the departure or extinction of *Megaceros*. Or, it may be that they were contemporaneous, but did not occupy the same districts.

Bones of the elk have been recorded from lake-dwellings at several localities in Switzerland: but in each case they have been associated with modern species of mammals, which do not indicate an earlier date than Neolithic.

M. Édouard Harlé [2] has described and figured the ungual phalange of an elk, from a deposit at La Plagnotte (Ariége) which he concludes to be transitional between the Quaternary and Recent periods. The same writer also says that the remains of elk are very rare in the South-east of France, a district well known to him, and that in no instance have they been detected among the numerous bones of mammals from the Quaternary deposits of that region. Earlier French writers, such as Jules de Christol [3] and Paul Gervais, [4] speak of the elk as occurring in the Diluvium of France; but it is open to question whether those described by Christol are really of Pleistocene age; and Gervais says that the elk appears to have left its remains in the Diluvium, but that they are few in number and the determination uncertain. It seems, therefore, that the elk was a rare animal in France in Pleistocene times, if indeed it was present there before the close of that epoch.

[1] W. H. Maxwell, 'Hill-side & Border Sketches' 8vo, London, vol. i (1847) p. 317.

[2] Bull. Soc. Géol. France, ser. 3, vol. xxviii (1900) p. 39.

[3] Ann. Sci. Nat. ser. 2, vol. iv (1835) p. 201.

[4] 'Zoologie & Paléontologie Françaises' 2nd edit. (1859) p. 143.

With regard to the presence of the elk as a fossil in Central Europe, Dr. Nehring[1] says that it is among the cervine mammals commonly found in Germany, in strata formed during the last thousand years, and is occasionally met with in 'Diluvial' deposits. In the first-mentioned paper the elk is given as present in Quaternary beds at five out of the twenty-four Central European localities enumerated; but in three of these instances the identification is doubtful, and it is only in these three that the remains were accompanied by *Elephas primigenius*. In the other two cases, although the deposits would be accepted as of Pleistocene age, *E. primigenius* has not been found in them.

The North American record of fossil *Alces* is very similar to that of Europe. Dr. O. P. Hay,[2] in his recently published Catalogue of the Fossil Vertebrata of North America, gives numerous references to a number of fossils, more or less closely allied to *Alces machlis*, from what are believed to be Pleistocene deposits; and Prof. S. W. Williston[3] describes a series of upper and lower grinding-teeth which he refers to *Alces* sp., from similar beds in Kansas. The evidence for the age of some at least of these remains needs verification; and it seems that in America, as in the Old World, *Alces machlis* must have been a rare animal in Pleistocene times.

The occurrence of elk-remains with those of mammoth, musk-ox, reindeer, and two forms of bison in the 'ice-cliffs' of Eschscholtz Bay, was pointed out long ago by Sir John Richardson[4]; but this does not necessarily indicate a Pleistocene antiquity for the elk in the far north, where the mammoth may have continued to live to a later time than it did in the more temperate latitudes of Europe.

A remarkable skeleton, with very aberrant though elk-like antlers, has been described from the Quaternary deposits of New Jersey by Prof. W. B. Scott[5] as a new genus, *Cervalces americanus*, on account of its presenting several characters apparently intermediate between *Cervus* and *Alces*. Mr. R. Lydekker,[6] however, regards this form as only specifically distinct from the elk, and names it *Alces Scotti*.

Prof. Cope gave the specific names of *Alces brevitrabalis* and *A. semipalmatus* to some fragmentary specimens from the *Equus*-beds (? Pleistocene) of Whitman County (Washington); but the specimens are very imperfect, and it is difficult to form an opinion as to their specific value.

Prof. W. Boyd Dawkins[7] has referred to the genus *Alces* certain

[1] 'Uebersicht über vierundzwanzig mitteleuropäische Quartär-Faunen' Zeitschr. Deutsch. Geol. Gesellsch. vol. xxxii (1880) p. 468; also Neue Deutsche Jagd-Zeitung, May 25th, 1889.
[2] Bull. U.S. Geol. Surv. No. 179 (1902).
[3] Univ. of Kansas Geol. Surv. vol ii (1897) p. 301 & pl. xlvii.
[4] 'Zoology of the Voyage of H.M.S. *Herald*' 4to, London, 1854, p. 20.
[5] Proc. Acad. Nat. Sci. Philad. 1885 [1886] p. 181.
[6] 'The Deer of All Lands' 1898, p. 60.
[7] 'British Pleistocene Cervidæ' Monogr. Palæont. Soc. 1886 (1887).

portions of antlers and skulls from the Cromer Forest-Bed, two of which had already been described as *Cervus latifrons* by Randall Johnson.[1] These specimens are distinguished from *Alces machlis* chiefly by the greater width of the frontals and the more elongated beam. Only one or two of these fossils show the commencement of the palmation, and the form of the antler is therefore unknown. These remains are the more interesting as showing the existence of an elk-like mammal in the Cromer Forest-Bed, which some of us regard as the latest stage of British Pliocene deposits.

The elk of Europe and moose of North America being regarded as one species (*Alces machlis*), its distribution at the present day is exceedingly wide in both the Old and New Worlds. In the former it is known in Scandinavia, Russia, Poland, Prussia, and Lithuania, extending as far north as the limit of arboreal vegetation; it is also found in Siberia and Tartary, as well as in the deserts of Altai and Baikal. In North America, it seems to have been found living very generally in suitable localities between the latitudes of 43° and 70° N., but not quite so far south on the eastern side of the continent as on the western. Unhappily, this interesting animal has been completely exterminated from certain localities, where formerly it was very abundant.

Records of British Fossil Elk-Remains.

1832. MEYER, HERMANN von. '*Cervus alces fossilis* (Fossiles Elenn).' Nova Acta Acad. Cæs. Leop.-Car. vol. xvi, p. 471.

1837. THOMPSON, W. ['Notes relating chiefly to the Natural History of Ireland.'] Proc. Zool. Soc. p. 53.

1847. MAXWELL, W. H. 'Hill-side & Border Sketches' 8vo, London, vol. i, p. 317.

1860. HARDY, JAMES. 'On Fossil Antlers of the Roebuck & Gigantic Irish Elk, found at Coldingham in 1859.' Proc. Berwickshire Nat. Club [1863] p. 206.

1861. HOWSE, RICHARD. 'Notes on the Fossil Remains of some Recent & Extinct Mammalia found in the Counties of Northumberland & Durham.' Trans. Tyneside Nat. Field-Club, vol. v (1863) p. 113 & pl. v.

1861. BATEMAN, THOMAS. 'Ten Years' Diggings in Celtic & Saxon Grave-Hills in the Counties of Derby, Stafford, & York' p. 298.

1862. SMITH, JAMES. 'Researches in Newer Pliocene & Post-Tertiary Geology' Glasgow, p. 42.

1864. LARTET, ÉDOUARD, & H. CHRISTY. 'Sur des Figures d'Animaux Gravées ou Sculptées, &c.' Revue Archéologique, n. s. vol. ix (1864) p. 250 footnote.

1868. 'ALCES.' The Elk. 'Land & Water' vol. v, no. 119, p. 233.

1869. OWEN, RICHARD. 'Note on the Occurrence of Remains of the Elk (*Alces palmatus*) in British Post-Tertiary Deposits.' Geol. Mag. vol. vi, p. 389.

1869. TINDALL, EDWARD. 'Remarks on the Extinct Fauna of the East Riding of Yorkshire. Proc. Geol. & Polytechn. Soc. Yorks. vol. v (1870) p. 7.

1872. SMITH, JOHN ALEXANDER. 'Notice of the Discovery of Remains of the Elk (*Cervus alces*, Linn., *Alces malchis*, Gray) in Berwickshire; with Notes of its Occurrence in the British Islands, more particularly in Scotland, &c.' Proc. Soc. Antiq. Scot. vol. ix, p. 297.

1876. YOUNG, JOHN. [Abstract of a paper on the Existence of the Elk (*Alces malchis*, Gray) in Scotland.] Proc. Nat. Hist. Soc. Glasgow, vol. ii, p. 176. [Read Nov. 25th, 1871.]

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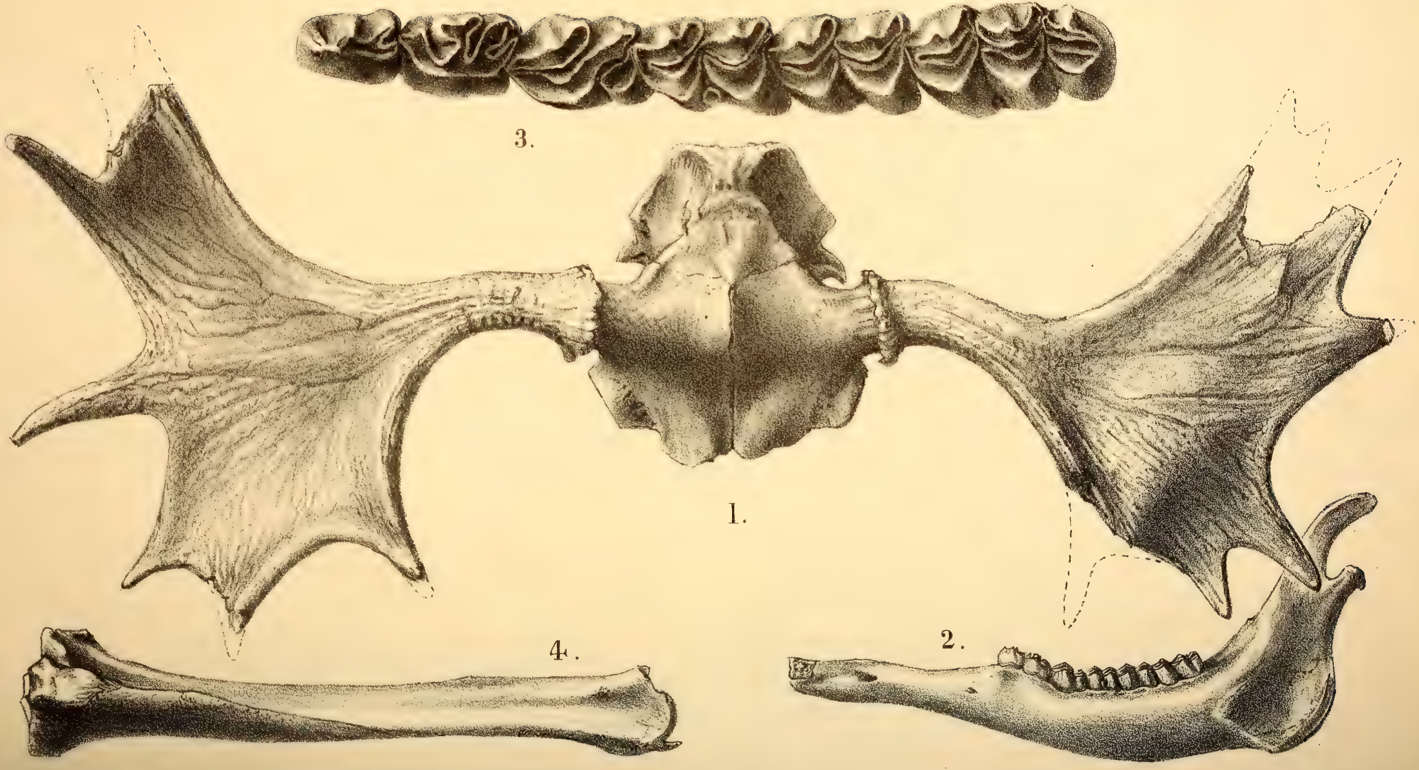
[1] Ann. & Mag. Nat. Hist. ser. 4, vol. xiii (1874) p. 1.



A. T. Hollick del. et lith.

Mintern Bros. imp.

ALCES MACHLIS (GRAY) FROM THE THAMES VALLEY.

1877. ADAMS, A. LEITH. 'Observations on the Remains of Mammals found in a Fossil State in Ireland.' Journ. Roy. Geol. Soc. Irel. vol. iv, p. 248.
1883. SMITH, J. A. 'Notice of the Occurrence of the Elk (*Cervus alces*, Linn., *Alces malchis*, Gray) recently found in Wigtownshire.' Proc. Soc. Antiq. Scot. n. s. vol. v, p. 325.
1885. LYDEKKER, RICHARD. Catal. Foss. Mamm. Brit. Mus. pt. ii, p. 78.
1887. DAWKINS, WILLIAM BOYD. 'British Pleistocene Cervidæ.' [Pt. vi of 'Brit. Foss. Mamm.'] Monogr. Palæont. Soc. vol. xl (for 1886).
1898. LYDEKKER, RICHARD. 'The Deer of all Lands' p. 49.

EXPLANATION OF PLATE V.

Remains of Elk (*Alces machlis*, Ogilby) from Thames alluvium near Staines.

(Figs. 1, 2, & 4 are about $\frac{1}{6}$ natural size; fig. 3 is about $\frac{2}{3}$ natural size.)

Fig. 1. Skull and antlers viewed from above and in front.
2. Left ramus of lower jaw seen from outside.
3. Left ramus: cheek-teeth, grinding-surface seen from above.
4. Left tibia, front view.

DISCUSSION.

The PRESIDENT referred to the remains of the elk discovered in the peat-bogs of the basin of the Tweed in the year 1871.

Prof. SOLLAS expressed the hope that the specimens deposited by Lartet in the University Museum at Oxford were not lost, but mislaid, and assured the Author that every facility should be afforded him if he would visit the Collection and look for them.

Mr. E. SLOPER suggested that the introduction of the elk into Britain was of later date than most persons imagined. The discovery of the remains in Thames alluvium with mammoth, for the first time, would scarcely afford evidence of the elk being older than the alluvium, and the mention of its existence with Roman remains and its deposit in peat brought to his mind a subject which he had investigated and written on that might be worth mentioning. He said that the notion that the City of London had been built upon a marsh was entirely erroneous. The original floor of London was situated on the brick-earth, which had been removed from time to time, forming huge pits filled up subsequently by rubbish, and through this rubbish up to the 17th century piles had been driven into the gravel, on which buildings were erected. These pits were the ancient 'leystalls,' consisting of all kinds of refuse, among other things rushes and straw used for domestic purposes, and this had been mistaken for peat. So much so, that the late Gen. Pitt-Rivers (then Col. Lane-Fox) had in 1867 published an article in the 'Anthropological Review' detailing the discovery of an early lake-dwelling in London Wall built upon piles, which are figured in that Review. Remains of *Bos longifrons*, wild deer, and wild goat were found. The particulars have since been embodied in Dr. Munro's 'Lake-Dwellings of Europe'; but in justice to

Gen. Pitt-Rivers, it is only fair to say that he remarks with regard to the thickness of the supposed peat :—

'It is difficult, if not impossible, to reconcile this enormous rise of 7 to 9 feet of peat during the four centuries of Roman occupation.'

The existence of the remains of the elk in peat and with the remains mentioned, therefore excited the speaker's curiosity, and it seemed to him that the many instances occurring in the North of England might lead to the possible conclusion that the introduction and domestication of the elk took place during the period of the Northmen and Danes, as that portion of the country was earlier affected by their invasion than the South of England. The domestication of the elk might have subsequently died out in Britain, as he believed that it had at a recent date in Norway and Sweden.

The AUTHOR, in reply, called attention to the fact that, although remains of *Alces machlis* had not been found with those of mammoth in Great Britain, yet it was associated with that species and reindeer in the frozen cliffs of Eschscholtz Bay—a fact noticed by Sir John Richardson in 1854, but which the Author thought was no proof of the Pleistocene age of the elk.

11. Observations *on the* Tiree Marble, *with* Notes *on others from* Iona. By Ananda K. Coomáraswámy, Esq., B.Sc., F.L.S., F.G.S. (Read December 17th, 1902.)

[Plates VI & VII.]

Contents.

I. Introduction.

Although so well known, and represented in many mineralogical collections, the Tiree Marble has never been described in detail. Macculloch [1] says that the Tiree flesh-coloured marble

'resembles the greater number of the primary limestones found in gneiss and mica-slate, and may be considered as a large nodule . . . The nodule of limestone . . . appears to be an irregular mass of about 100 feet in diameter, and is surrounded on all sides by gneiss.' [The marble] 'occasionally contains imbedded lumps of granite or gneiss, similar to those which occur in the limestone of Glen Tilt. These are always visible at the surface, from their superior power of resisting the action of the atmosphere.'

He also describes the exposures of limestone in a field south-east of Balephetrish Hill. He says that

'it is possible that the masses of limestone thus found in gneiss have once been stratified, and that they have suffered some posterior changes by which the appearances of this disposition have been obliterated.'

Prof. Bonney [2] has given a valuable description of the dynamic phenomena so well illustrated in thin sections of the Tiree Marble.

Prof. Cole & Prof. Sollas [3] have suggested that the Tiree Marble may originally have been a wind-blown coral-sand rock, with abundant rounded crystals of detrital augite, etc., such as was found on the east side of Mèr, one of the Murray Islands. This theory appears untenable; for it is impossible to imagine a volcanic origin for the majority of the accessory minerals, which, with the exception of felspar, are, on the contrary, the typical accessory and contact-minerals associated with crystalline limestones in all parts of the world.

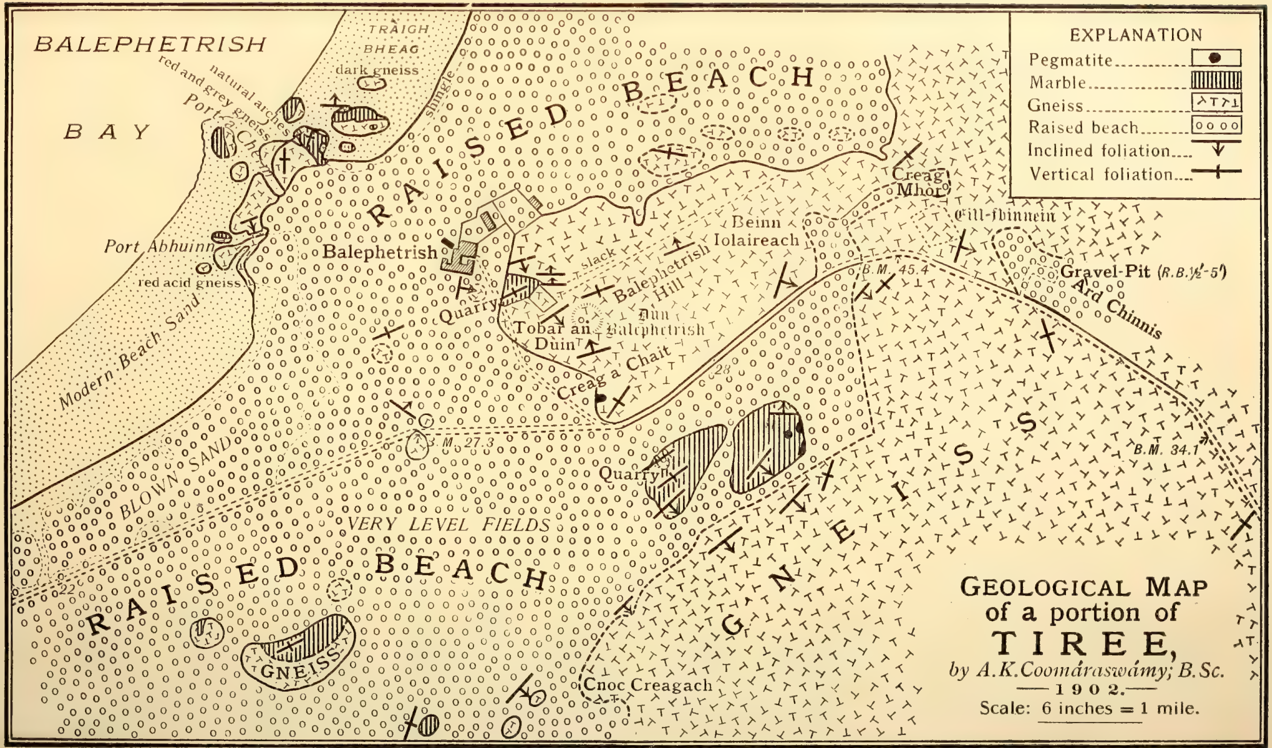
This paper embodies observations made by me in the summer of the present year (1902).

[1] 'Western Islands of Scotland' vol. i (1819) pp. 48 & 49.

[2] 'The Effects of Pressure on Crystalline Limestones' Geol. Mag. 1889, p. 483.

[3] 'The Origin of certain Marbles: a Suggestion' Sci. Proc. Roy. Dublin Soc. vol. vii (1891) p. 124; see also Haddon, Sollas, & Cole, 'On the Geology of Torres Straits' Trans. Roy. Irish Acad. vol. xxx (1892–96) pp. 436, 470.

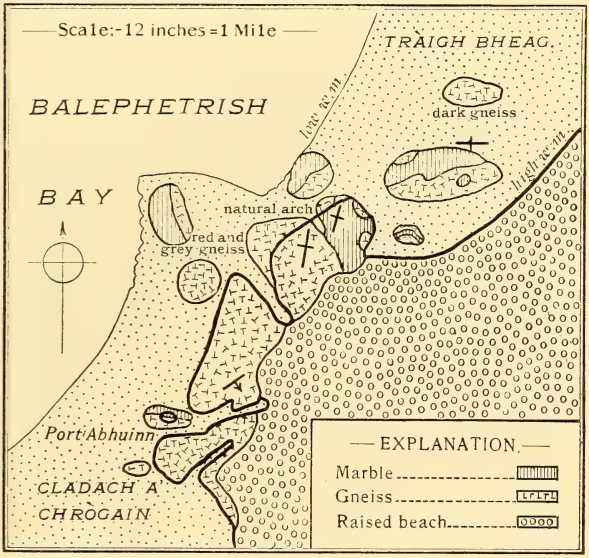
Fig. 1.


EXPLANATION
Pegmatite
Marble
Gneiss
Raised beach
Inclined foliation
Vertical foliation
BALEPHETRISH
BAY
TRAIGH BHEAG
dark gneiss
natural arches
red and grey gneiss
Port a Chenn
shingle
Port Abhuinn
red acid gneiss
Modern Beach Sand
RAISED BEACH
Balephetrish
Quarry
Beinn Iolaireach
slack
Balephetrish Hill
Dun Balephetrish
Tobar an Duin
Creag a Chait
Creag Mhor
Cill-fhinnein
Gravel-Pit (R.B.½'-5')
Ard Chinnis
B.M. 45.4
B.M. 34.1
B.M. 27.3
28
22
BLOWN SAND
VERY LEVEL FIELDS
RAISED BEACH
GNEISS
Quarry
GNEISS
Cnoc Creagach
GEOLOGICAL MAP
of a portion of
TIREE,
by A.K.Coomáraswámy; B.Sc.
1902.
Scale: 6 inches = 1 mile.

II. General Description.

The exposures of marble and gneiss near Balephetrish are shown in the accompanying maps (figs. 1 & 2). Unfortunately, the relations are much obscured by more recent deposits. It is clear, however, that the gneiss has a general south-westerly and north-easterly trend, and that the masses of limestone occur as lenticles of various size in the gneiss, exhibiting a similar foliation. The latter in the gneiss is more or less interrupted by the large limestone-augen round which it sweeps, and the result is great local irregularity in its direction; the foliation of gneiss and limestone is, however, always parallel.

Fig. 2.—*Enlargement of a portion of fig. 1.*



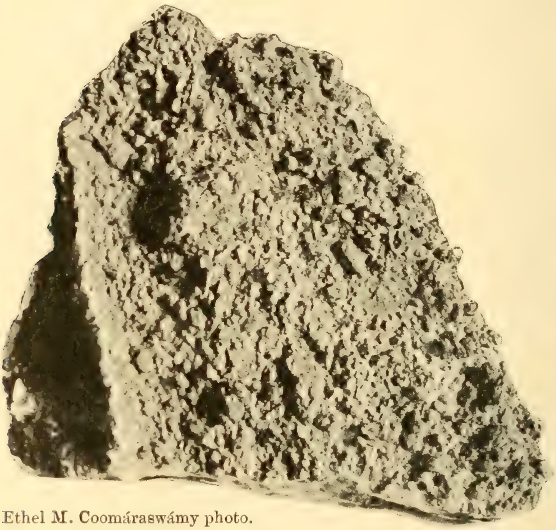
On the shore west of Balephetrish the two rocks are most intimately associated, some quite small inclusions and narrow streaks of marble, besides larger masses, occurring in the gneiss.

The marble is by no means of uniform character; it will be simplest to give brief descriptions of the main types noticed.

(1) Pink marble of Balephetrish Quarry.—This is the well-known Tiree Marble, so common in collections. The rock consists of minutely granular calcite, with some subordinate dolomite; embedded in this compact carbonate-matrix are abundant crystals of dark-green hornblende (often idiomorphic), and coccolite, with scarcer greenish-brown mica, and minute brilliant grains of pale hair-brown sphene. In other specimens coccolite is the predominant or only silicate. Minute crystals of scapolite were also found (in residues) by the late Prof. Heddle.

(2) Pink marble from Port Abhuinn (see map, fig. 2, p. 93).—This rock much resembles the marble from Balephetrish Quarry. It consists of calcite, generally very fine-grained, the result of shearing and strain, the effects of which are well displayed; a few larger individuals are stretched out, bent, and twinned (Pl. VII, fig. 2); occasional grains have been preserved uncrushed where protected by silicates, in the manner described by Prof. Bonney. Coccolite, green in hand-specimens, very pale in sections, is abundant; rounded

Fig. 3.—*Limestone, with inconspicuous foliation, and abundant forsterite weathered out on the surface. Fields south-east of Balephetrish Hill. (About $\frac{2}{3}$ nat. size.)*



Ethel M. Coomáraswámy photo.

[Sahlite, tremolite, mica, and spinel also occur, very sparingly, on this specimen.]

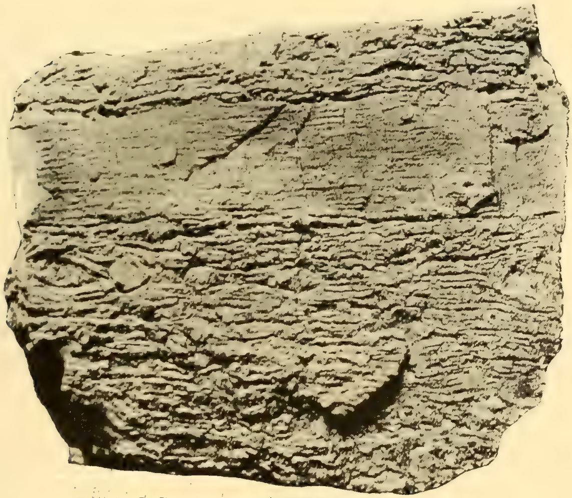
grains of orthoclase are common; a decomposed mineral, which is probably scapolite, occurs; and there are tiny grains of sphene sparsely scattered through the rock. The same rock, thoroughly mylonized, and containing blocks of gneiss in the crush-breccia (fig. 5, p. 99), is of a grey colour, and has a smooth, flinty, conchoidal fracture.

(3) Grey marble from south side of field, south-east of Balephetrish Hill (fig. 3).—Here the carbonate-matrix is less broken down than in the other types described; the cleavage-faces of carbonate-crystals can be clearly seen on a freshly-broken surface. Microscopic examination shows that much of the carbonate-matrix is, however, as usual, very fine-grained and compact; the larger grains

are usually dolomite, the finer material stains like calcite. Other minerals include:—(*a*) Very abundant forsterite: the crystals weather-out as brownish lumps on the surface of the limestone; under the microscope complete or partial serpentinization is characteristically displayed. (*b*) Scarce colourless mica, tremolite, and sahlite. (*c*) A few scattered grains of greenish-blue spinel: this mineral was not observed at any other point, and even here occurs in very limited amount.

(4) A white marble from the small quarry in the same field (fig. 4).—This rock is generally similar to the last-described, but is

Fig. 4.—*Limestone similar to that of fig. 3, but of finer grain and well-foliated. From a small quarry in the same field. (About $\frac{4}{5}$ nat. size.)*



Ethel M. Coomáraswámy photo.

[The small augen consist usually of forsterite.]

finer-grained and more compact, and conspicuously foliated. The silicates are forsterite and sahlite, which appear as ovoid augen, round which the foliation sweeps (fig. 4), giving quite a gneissose aspect to the rock.

Various inclusions are characteristic of the Balephetrish marbles. They may be classed as (1) gneiss-inclusions, and (2) mineral-aggregates.

(1) Gneiss-inclusions.—These occur in the pink marble at Balephetrish, and in similar marbles on the shore west and north-west of Balephetrish. The minerals characteristic of these inclusions include quartz, felspars, hornblende, augite, scapolite, and sphene.

The presence of some of these inclusions is evidently the result of crush-brecciation (fig. 5, p. 99); others seem to be more or less modified portions of intruded rock, and recall similar inclusions in the crystalline limestones of Ceylon.

There occur also small pegmatite-patches in the eastern part of the exposures of marble in the field south-east of Balephetrish Hill.

(2) Mineral-aggregates.—Small and large augen of pure white sahlite (the largest measuring 6 feet by 4) occur in the white marble of the field south-east of Balephetrish Hill; the foliation of the marble sweeps around these on a large scale, just as on a smaller scale it bends round the little augen consisting of single grains of diopside or forsterite.

Near the spot marked 'Natural Arch' numerous dark mineral-aggregates occur in the pink marble, varying in size from a few inches to a foot or two in diameter, and of quite irregular lumpy shape. These weather out on the surface, being often attached by quite a narrow neck. They consist of dark-green coccolite, scapolite, sphene, and blue apatite, with also calcite and colourless or brown mica (Pl. VII, fig. 3). The first four minerals are especially characteristic; the rock strongly recalls certain augite-scapolite-sphene rocks from Ceylon.[1] The grains of apatite are rather conspicuous, owing to their bright sky-blue colour; this occurrence of blue apatite again reminds one of Ceylon.

III. Contact-Phenomena.

Contact-phenomena are not especially well displayed, partly owing to the earth-movements which have affected the rocks since their formation, partly owing to the fact that contact-sections are rather infrequently exposed.

A contact of limestone with gneiss of acid type is seen at the southern edge of the quarry at Balephetrish. The gneiss is composed of quartz and felspar, exhibiting strain-shadows and partial granulitization; a few rather large grains of zircon occur in addition. The marble is one of the finest-grained types, with appearances of 'streaming,' and with numerous grains of coccolite and also decomposed scapolite (?) and sphene. A dark zone, about half an inch wide, separates typical marble from typical gneiss. In this zone, on the side next the gneiss, the minerals hornblende and felspar (triclinic), with a little accessory golden-brown mica, compose the rock, while greenish pyroxene is rare. On the side next the marble the zone contains pale-green monoclinic pyroxene (that is, coccolite), scapolite with rather abundant sphene, and accessory iron-ores. The change from hornblende-felspar-rock (modified gneiss) to pyroxene-scapolite-rock (altered limestone) takes place rather abruptly near the middle of the half-inch dark zone; but the

[1] A. K. Coomáraswámy, Quart Journ. Geol. Soc. vol. lviii (1902) pp. 407 & 680.

minerals are completely interlocked, and there is no actual line of junction seen under the microscope, although an abrupt change is evident. The rock has suffered from frequent minute faulting and slight shearing, the effects of which are quite distinct in the gneiss and contact-zone, but are lost as they pass into the compact marble. The original relations are not obscured. It is rather curious that the only rock here seen in actual contact with the marble should be this quartzo-felspathic gneiss or granulite, while the prevailing rocks at Balephetrish are of a dark hornblende-plagioclase type.

At many points on the shore contacts of marble and gneiss (usually of acid type) are to be seen. In some cases, as, for example, near the 'Natural Arches,' a zone of grey rock composed of monoclinic pyroxene separates typical limestone from gneiss; in other cases, no very striking contact-phenomena attract attention.

Enclosures of gneiss in marble appear often to have been much modified by the absorption of lime, with the development of pyroxene, scapolite, and sphene; in one case (Port-Abhuinn marble) a large inclusion of gneiss was separated from the typical marble by a narrow zone of pyroxene-scapolite-sphene-rock, with apatite and calcite, essentially resembling the rock of a narrow contact-zone described above, and of the mineral-aggregates occurring in the marble at the 'Natural Arches.'

The presence of accessory minerals in the limestone is in itself to be regarded as evidence of contact-metamorphism. It is shown below that the rounded character of some of these affords no evidence of detrital origin, such as has been suggested[1]; grains of rounded coccolite and sphene are associated with idiomorphic hornblende. I have no doubt that all these minerals have crystallized *in situ*: probably under conditions analogous to those of minerals crystallizing in a cooling magma, when, moreover, the limestone perhaps existed in a state akin to fusion.

IV. Dynamic Phenomena.

In some varieties of limestone foliation is inconspicuous, and the silicates are frequently idiomorphic. In others it is very distinct; and the included minerals are rounded, and form little augen round which it sweeps (fig. 4, p. 95). The rounded outline of the silicate-minerals is frequently, however, an original character: thus the grains of coccolite and sphene in the pink Balephetrish marble have smooth rounded forms, but are associated with sharply idiomorphic hornblende, showing that the rounded form is for these minerals a characteristic habit rather than a secondary phenomenon.

The effects of pressure are most conspicuous in the carbonates. These are usually present as the fine-grained, granular, compact matrix, in which various silicates are embedded. The various thin sections examined show most clearly that the minutely granulated condition is a result of the complete breakdown of larger grains,

[1] G. A. J. Cole & W. J. Sollas, Sci. Proc. Roy. Dublin Soc. vol. vii (1891) p. 124; A. Harker, 'Petrology for Students' 2nd ed. (1897) p. 317.

fragments of which are sometimes preserved (see Pl. VII, fig. 4), and that the limestone as a whole must once have possessed a more coarsely crystalline character, as was pointed out by Prof. Bonney several years ago.[1] These phenomena are illustrated in Pl. VI, fig. 1, and Pl. VII, figs. 1 & 2. Other examples of marble showing cataclastic structure are described and illustrated by Messrs. Adams & Nicolson,[2] who have reproduced experimentally the same phenomena. If we accept the results of their experiments, we must conclude that the deformation of the Tiree Marble is the result of pressure, acting at a temperature not above 300° C. We are, then, observing the effects of dynamometamorphism, free from complications due to marked accompanying thermal metamorphism. This must apply also to the gneisses with which the limestone is associated: a detailed examination of these has not been made; they have certainly suffered from minute faulting and local shearing, but to a small extent, compared with the gneissose rocks of Iona, or, for example, of the Loch-Maree district. The gneisses are of a general Lewisian type, and include dark hornblendic rocks composing Balephetrish Hill, and also quartzo-felspathic gneisses which are more abundant on the shore. Coarse rocks of granuloid or pegmatitic aspect, and with inconspicuous foliation, occur near the road farther east.

An interesting crush-breccia (fig. 5, p. 99) occurs at the junction of limestone and gneiss, at Port Abhuinn, on the shore west of Balephetrish. Here we find a foot or two of completely mylonized limestone, having a smooth flinty conchoidal fracture, containing numerous blocks of gneiss, which have also suffered from the pressures. The calcareous matrix has a delicate 'flow-structure,' resembling that of a rhyolite. Something of the same kind has taken place quite locally near the spot marked 'Natural Arch' on the shore. There are gneissose streaks and patches in the limestone, and the two rocks are sheared together. The marble is a fine-grained calcite-rock, with diopside-grains more or less twinned and strained and bent. The sheared gneiss consists of a fine-grained foliated matrix of felspar and calcite-dust, with rounded scapolite and triclinic felspars with undulose extinction, broken porphyritic augite, and occasional hornblende and sphene. A dark intervening zone contains augen of felspar, hornblende, and sphene, and is perhaps the remnant of a contact-zone. It is more usual, however, for gneiss-inclusions and mineral-aggregates (Pl. VII, figs. 3 & 4) in the limestone to have been more or less protected from the extreme effects of pressure.

V. Notes on the Minerals.

The following minerals occur in the limestones or in the mineral-aggregates found in them :—Calcite, dolomite, pyroxene, amphibole, forsterite, scapolite, mica, sphene, apatite, orthoclase, spinel, and serpentine.

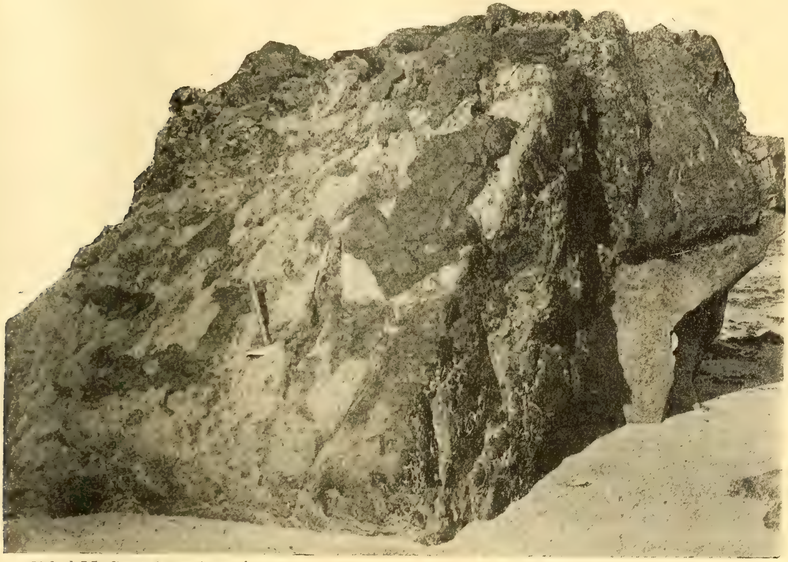
[1] 'The Effects of Pressure on Crystalline Limestones' Geol. Mag. 1889, p. 483.
[2] 'An Experimental Investigation into the Flow of Marble' Phil. Trans. Roy. Soc. vol. cxcv (1901) A p. 387 & pls. xxii–xxv. Compare especially pl. xxv, figs. 3 & 4 with my figures.

Carbonates.—In most cases calcite is the predominant carbonate; it is rare for dolomite to be abundant. The deformation and granulitization of the carbonates are referred to above. Heddle [1] gave the following percentage analysis of Tiree Marble:—

$$CaCO_3=95{\cdot}94;\ MgCO_3=1{\cdot}78;\ FeCO_3=0{\cdot}576;\ MnCO_3=1{\cdot}028.$$

Pyroxene.—The Tiree Marble has always been noted for its 'coccolite.' This mineral (which is not more characteristic of the

Fig. 5.—*Crush-conglomerate on the shore west of Port Abhuinn: mylonized limestone with gneiss-inclusions.*



Ethel M. Coomáraswámy photo.

pink Balephetrish marble than is amphibole) appears to vary in colour from light to dark green, nearly black, the latter colour being characteristic of the mineral-aggregates, composed of pyroxene, scapolite, sphene, and blue apatite. I have in this paper spoken of the coloured pyroxene associated with the marble as coccolite, and called the white pyroxene sahlite, as this name has been employed by previous authors. Masses of sahlite form large and small augen in the white marble in the field south-east of Balephetrish Hill. An analysis of sahlite by Heddle [2] is here quoted:

$$SiO_2=50{\cdot}54;\ Al_2O_3=4{\cdot}69;\ Fe_2O_3=4{\cdot}14;\ FeO=0{\cdot}04;\ MnO=0{\cdot}69;$$
$$CaO=23{\cdot}59;\ MgO=14{\cdot}4;\ K_2O=0{\cdot}31;\ Na_2O=0{\cdot}63;\ H_2O=1{\cdot}48.$$
$$\text{Total} = 100{\cdot}51.$$

Heddle appears to classify all the pyroxene as sahlite, as he says

[1] 'Mineralogy of Scotland' vol. i (1901) p. 137. [Mr. E. C. C. Stanford gave analyses of Tiree Marble, Rep. Brit. Assoc. 1870 (Liverpool) Trans. Sect. p. 65.—Ed.]

[2] Trans. Roy. Soc. Edin. vol. xxviii (1879) p. 460.

that the sahlite may be dark-green, light-green, or grey, and does not mention coccolite as actually occurring in the limestone at all. A more detailed chemical examination of these pyroxenes with reference to colour seems desirable.

The pyroxenes are often twinned, and even distorted, in those varieties of limestone which have suffered most severely from the pressures (Pl. VI, fig. 2).

Amphibole.—Dark-green amphiboles are very characteristic of the pink Balephetrish marble, and are often of large size, and then sometimes intergrown with carbonates. Individuals are frequently idiomorphic (Pl. VII, fig. 6). The pleochroism is $\mathfrak{a}$ pale greenish-straw, $\mathfrak{b}$ olive-green, $\mathfrak{c}$ bluish-green; the extinction-angle on flakes = about 23°. Colourless tremolite occurs in other varieties of limestone.

Forsterite.—This mineral (not hitherto recorded from Tiree) occurs abundantly in some varieties of limestone, especially in the white limestone exposed in a field south-east of Balephetrish Hill. Crystals are never idiomorphic, but elongated individuals extinguish in the direction of their length, and examination in convergent polarized light shows that the axial plane is at right angles to the direction of elongation. Partial or complete serpentinization, commencing along the irregular cracks, is typically exhibited.

The forsterite from a specimen (fig. 3, p. 94 & Pl. VII, fig. 1) of marble from the south side of the field has been analysed by Mr. W. C. Hancock, B.A. Weathered, but carefully selected crystals were used for this analysis, which confirmed the identification of forsterite. The specific gravity was 2·80.

Scapolite.—This mineral was found by Heddle in the residues from the pink Balephetrish marble, in rare minute crystals, with the forms $a(100)$, $m(110)$, $r(111)$, associated with sahlite and white biotite. His analysis is as follows [1]:—

SiO_2=48·923; Al_2O_3=22·098; Fe_2O_3=3·159; FeO=1·508; MnO=0·538; CaO=7·753; MgO=2·769; K_2O=6·058; Na_2O=1·679; H_2O=5·694.

I have found it much more abundant, in larger, not idiomorphic grains in mineral-aggregates (associated with coccolite, sphene, and apatite), in modified gneiss-inclusions, and in contact-zones.

Sphene.—Small, lustrous, blunt-angled crystals, of a watery-brown colour, occur sparingly in the pink marbles. Larger grains occur more abundantly in the coccolite-scapolite-sphene aggregates, and in some varieties of contact-rock or modified gneiss-inclusions. The grains have sometimes quite a pinkish colour; they were mistaken by Jameson [2] for garnet.

Mica.—Rather decomposed, colourless flakes of mica occur in some varieties of limestone and in mineral-aggregates. No typical phlogopite occurs. Dark-brown mica is occasionally seen in mineral-aggregates.

Apatite.—Grains of sky-blue apatite (not hitherto recorded from Tiree) are found rather plentifully in the coccolite-scapolite-sphene

[1] 'Mineralogy of Scotland' vol. ii (1901) p. 53.

[2] 'Mineralogy of the Scottish Isles' vol. ii (1800) p. 32.

aggregates occurring in the limestone near the 'Natural Arches' on the shore. The grains are often elongated in the direction of the vertical axis, but are not idiomorphic; in thin sections they are practically colourless. The grains are only faintly pleochroic, showing a bright sky-blue for rays vibrating perpendicular to the vertical axis, and a paler greenish-blue for rays vibrating parallel thereto. Individual grains vary in colour from bright sky-blue to a duller bluish-green. Possibly this apatite is the mineral spoken of by Heddle[1] as a 'pale-blue watery variety' of sahlite. Mr. W. C. Hancock, B.A., has carefully analysed the blue apatite, with the following result:—

$Cl = 1{\cdot}85$; $SiO_2 = 1{\cdot}5$; $CaO = 53{\cdot}92$; $P_2O_5 = 39{\cdot}55$; and H_2O (hygroscopic) $= 3{\cdot}16$. Total $= 99{\cdot}98$. Specific gravity $= 3{\cdot}20$.

This analysis shows that the blue apatite of Tiree is one of the comparatively rare chlor-apatites, and much resembles analyses of chlor-apatite given by Vœlcker.[2]

Spinel.—A few grains of bluish-green spinel (not hitherto recorded from Tiree) are scattered very sparingly in a variety of marble (No. 3, p. 94) exposed in the field south-east of Balephetrish Hill. The accompanying silicates are:—abundant forsterite, and scarce mica, tremolite, and sahlite. The spinel is quite isotropic; and in thin chips nearly colourless. Mr. G. T. Prior, M.A., F.G.S., has kindly determined the specific gravity as 3·635. The spinel is probably referable to pleonaste.

VI. Iona.

Marble is exposed on the shore south of Dun Dugaidh; a long 'slack' leads down to the—from the sea—rather inaccessible beach known as the 'Marble Quarry.' Much white marble occurs here: portions are greenish or black. It has a silky, almost schistose aspect; it seems to occur as a band or lenticle in the gneissose rocks. The colourless varieties consist of calcite, with some serpentine and tremolite, the last-named in small needles often felted together. In the dark patches serpentine is more abundant, and may practically compose the rock. The rocks immediately associated with the marble include actinolite-felspar schists with epidote and pyrite (north wall of 'slack'); hard white rocks, excessively fine-grained, resembling the marble but composed of felspar and muscovite (?) with zoisite. Associated with these was a band of mica-schist-like rock, composed of finely granular quartz, mica, and felspar, with actinolite and pyrite, and exhibiting well-marked foliation. This rock suggests an altered sediment. There are, moreover, bands and streaks of dark rock, hard and heavy, in the marble itself; these are actinolite-felspar-schists, with much pyrite and some epidote. The orientation of the needles of actinolite is very marked, the ether-axis $\mathfrak{c}$ being parallel to the foliation. All these rocks appear to have been entirely reconstructed.

[1] Trans. Roy. Soc. Edin. vol. xxviii (1879) p. 459.
[2] Rep. Brit. Assoc. 1857 (Dublin) Trans. Sect. p. 59.

A small exposure of highly sheared silky limestone occurs near the commencement of the path at the beginning of the grassy flat (raised beach) above St. Columba's Bay (Port-a-Churaich); it forms a band in the gneiss, with corresponding foliation. It contained a few small silicate-augen: one consisting of colourless monoclinic pyroxene, with secondary tremolite and calcite; another of felspar and calcite, with zoisite and amphibole. The felspar is mostly triclinic; there is some orthoclase and orthoclase-microperthite; in the latter the inclusions of triclinic felspar have sometimes given rise to secondary calcite, producing a (secondary) banded intergrowth of calcite and orthoclase.

Finally, there is a band of limestone or ophicalcite (locally called sunstone) in the gneiss about a quarter of a mile north-east of Port Bán, on the western coast of Iona. The rock is less crushed than those above described, and consists of granulated calcite with equally abundant flakes of colourless mica (often bent) and rounded grains of serpentine, the last-named very possibly a pseudomorph after forsterite, and also grains of nearly colourless sphene. A single large crystal of decomposed pyroxene was also observed.

The limestones just described from Iona are included in the gneiss. The latter is of varied character, though hornblendic types are perhaps most usual; it has nearly everywhere suffered much from pressure.

Sedimentary rocks suggestive of Torridon Sandstone occur along the eastern shore of Iona, especially in the northern half of the island; they include felspathic grits and finer slaty or shaly bands. They become very much sheared, especially as the junction with gneiss is approached; there would be much difficulty in drawing a satisfactory boundary. The limestones above described are not associated with these sediments, but entirely included in the gneisses, and seem to correspond to rocks such as the Tiree Marble, but which have suffered much more from the effects of pressure, so that we cannot study the original relations or even point to original minerals. The ophicalcite from near Port Bán, however, more nearly resembles the Tiree Marble; differing chiefly in the absence of any portion of the mineral now replaced by serpentine.

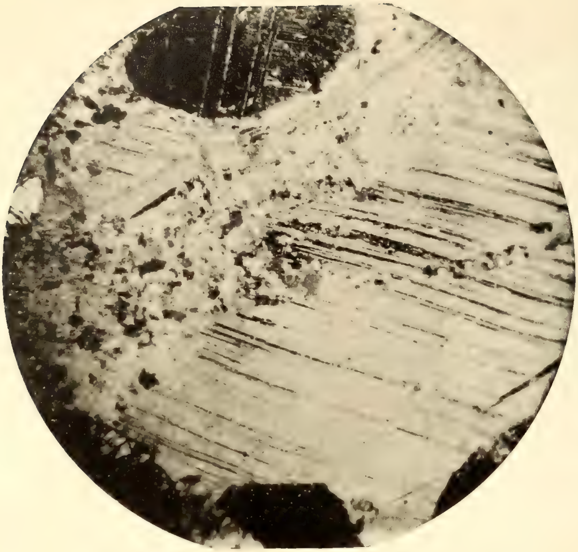
VII. Summary and Conclusions.

Tiree.

(*a*) The various patches of marble occur as lenticular masses in the gneiss. There is no evidence as to the origin of the limestone.

(*b*) The development of the accessory minerals and probably also the original more coarsely crystalline character of the marble, are the result of contact-metamorphism at high temperature.

(*c*) The hornblendic and acid orthogneisses associated with the marbles were the agents in this thermometamorphic process.



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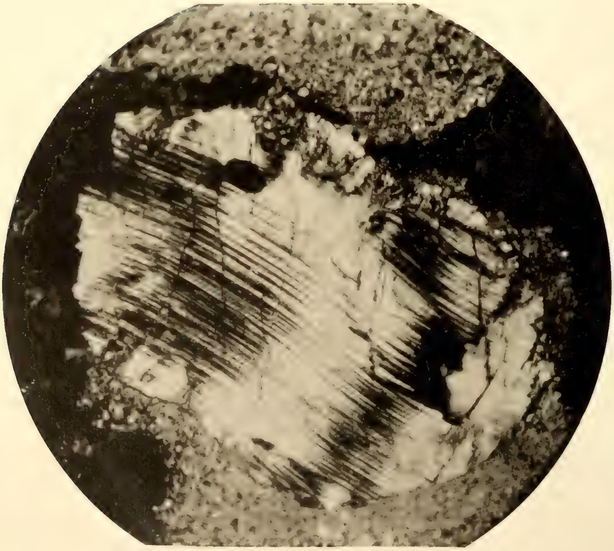
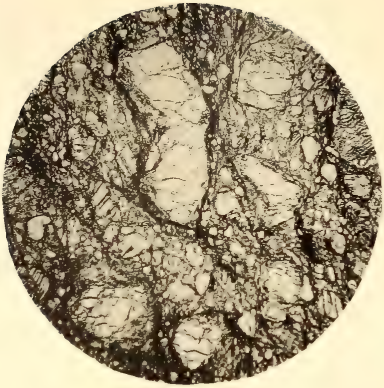


2.

A. K. Coomáraswámy, photomicro. Bemrose, Ltd., Collo.

"Tiree Marble."



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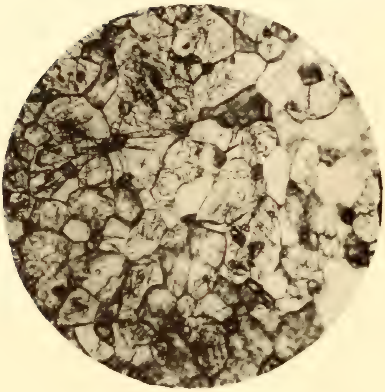

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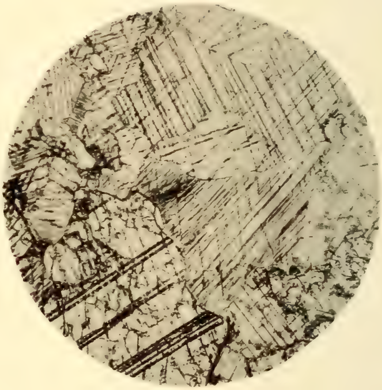

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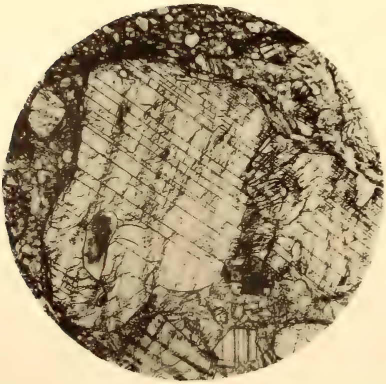

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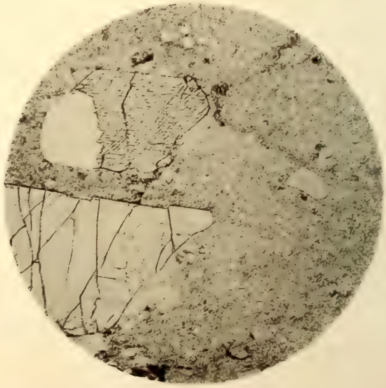


6.

A. K. Coomáraswámy, photomicro. *Bemrose, Ltd., Collo.*

"Tiree Marble."

(*d*) The present foliation of the marble and possibly in part of the gneiss, together with the various dynamic phenomena displayed by the marble (and gneiss), is the result of subsequent dynamic metamorphism unaccompanied by any marked thermal metamorphism.

Iona.

The marbles of Iona were very probably originally similar to those of Tiree, but have, in most cases, suffered more severely from dynamic metamorphism.

EXPLANATION OF PLATES VI & VII.

Plate VI.

Fig. 1. Incipient cataclastic structure in carbonates. Fields south-east of Balephetrish Hill. × 33, crossed nicols. (See p. 98.) Slide 1027, Author's collection.

2. Twinned and bent crystal of sahlite, in the mylonized limestone of the crush-conglomerate, Port Abhuinn. × 26, crossed nicols. (See p. 100.) Slide 1033, Author's collection.

Plate VII.

Fig. 1. White limestone with forsterite (and sahlite); the lines of crushing are well seen in the carbonate-matrix. From small quarry in field south-east of Balephetrish Hill. × about 9. (See pp. 98 & 100.) Slide 1022, Author's collection.

2. Cataclastic structure in pink marble; bending, shearing, and break-up of calcite-grains. The large transparent grain is orthoclase. Port-Abhuinn marble. × 12. (See pp. 94 & 100.) Slide 1034, Author's collection.

3. Aggregate composed of coccolite and scapolite with sphene, (blue) apatite, calcite, and mica. Natural Arch, shore, Balephetrish. × 15. (See p. 96.) Slide 1040, Author's collection.

4. Silicate-aggregate, with abundant calcite and dolomite; the carbonates uncrushed. Same locality. × about 13. (See p. 99.) Slide 1025, Author's collection. The nearly central small dark patch is an appearance due to local incipient breakdown of a calcite-grain.

5. Sahlite in the same slide as fig. 1; basal cleavage well developed. × about 8.

6. Idiomorphic amphibole, in fine-grained pink marble, Balephetrish Quarry. × about 11. (See p. 100.) Slide 1019, Author's collection.

Discussion.

The President spoke of the fine series of microscope-sections exhibited by the Author, and of the evidences of movement and of mylonization which they presented. The proofs of contact-alteration of the calcareous rock by the gneiss seemed clear, and the association of minerals was reminiscent of that shown in the case of the Ledbeg Marble. Was it impossible that the Tiree lenticles, which had the same trend as the Ledbeg rock, were relics of a south-westerly extension of the same calcareous formation? The conclusion that the Tiree Marble was a limestone which had been

first intruded upon, enveloped, and metamorphosed by igneous rock, and that afterwards the resulting complex had been subjected to dynamic movements bringing about mylonization, was simple, and appeared to agree with most of the phenomena cited. It would be interesting, however, to know whether there was anything apparent to disprove the theory that the injection and the main dynamic action were simultaneous; or, in view of the experiments of Adams & Nicolson, that the crystals of calcite, etc. might not have developed and enlarged even under pressure; or that the original limestone might not have undergone dynamic action before the injection; or that the entire complex itself might not have been squeezed and yielded more than once afterwards.

Prof. Bonney said that his knowledge of the Tiree Marble was founded on hand-specimens and rock-slices only, as he had never visited the place. Still, in the Alps, he had had so many opportunities of studying the effects of pressure on crystalline limestones, that he could venture to say that the suggestion thrown out by the President as to the coarser calcite-grains in the marble being recrystallized, was no more probable than that the felspar-grains in the 'mylonites' of Glen Laggan were recrystallized. The coarse calcite might be sometimes seen to have been protected between two grains of sahlite, like a bay between headlands. He called attention to some analogies between the Tiree rock and the well-known crystalline limestones of Côte St. Pierre (Canada), and said that he did not think any close connexion existed between it and the Ledbeg Marble. The paper to which the Society had listened appeared to him to make a valuable addition to knowledge.

Prof. Sollas thought that the Ledbeg limestone owed its character to contact-metamorphism, that of Tiree to this action and something more; for it appeared to be a very mixed product, and some of its minerals might have been originally deposited along with calcareous sediment, just as olivine-sands are now being mingled with calcareous sands on the shores of Sawaii. Some of the felspar of the Tiree Marble presented evidence of secondary growth; and that felspar might be formed by subsequent growth within a 'calciphyre' was shown by Issel's observations on radiolaria included within albite-crystals, which occurred as constituents of the so-called 'calciphyre' of Rovegna in the Val di Trebbia.

The Author said that he saw no reason for connecting the Ledbeg and Tiree Marbles, the former being post-Torridonian, the latter in all probability pre-Torridonian. It was quite clear that recrystallization had not taken place since the production of cataclastic phenomena. Contact-phenomena were unmistakable in places. He thought that there was little to suggest a detrital origin for the accessory minerals. With the exception of the, not very abundant, felspar, it would be very hard to imagine a volcanic origin for these.

12. *On the* Discovery *of an* Ossiferous Cavern *of* Pliocene Age *at* Doveholes, Buxton (Derbyshire). By William Boyd Dawkins, M.A., D.Sc., F.R.S., F.S.A., F.G.S., Professor of Geology in Owens College (Victoria University), Manchester. (Read January 7th, 1903.)

[Plates VIII–XII.]

Contents.

I. Introduction.

The Carboniferous Limestone, riddled with fissures and potholes in the neighbourhood of Doveholes, and largely occupied by extensive quarries, has from time to time yielded remains of the extinct mammalia. A tusk of mammoth, from a fissure in one or other of these quarries, has been preserved in the Owens College Museum for the last half-century. The latest discovery of a group of mammals of far higher antiquity than the mammoth, which I propose to bring before the Society in this communication, was primarily due to Master Hick (who happened to pick up some teeth of *Mastodon* while rambling over the quarry with other boys) and to Mr. Salt, the well-known Buxton antiquary, who showed me the specimens, along with others which he found at a later time. I am indebted to him for placing the specimens in my hands and giving me all the information at his command, and to the Committee of the Free Library & Museum of Buxton for the loan of specimens. I have also to thank the owner of the quarry, Mr. S. Bibbington, for allowing me to obtain, for the Owens College Museum, the specimens which have from time to time been discovered, as the cave in which they rested was opened out by the work in the quarry. I have further to acknowledge the services of the foreman of the quarry, Mr. Gregory, and of Mr. Hall, assistant-

Fig 1. Map of the district round VICTORY QUARRY. Scale: 6 inches = 1 mile.

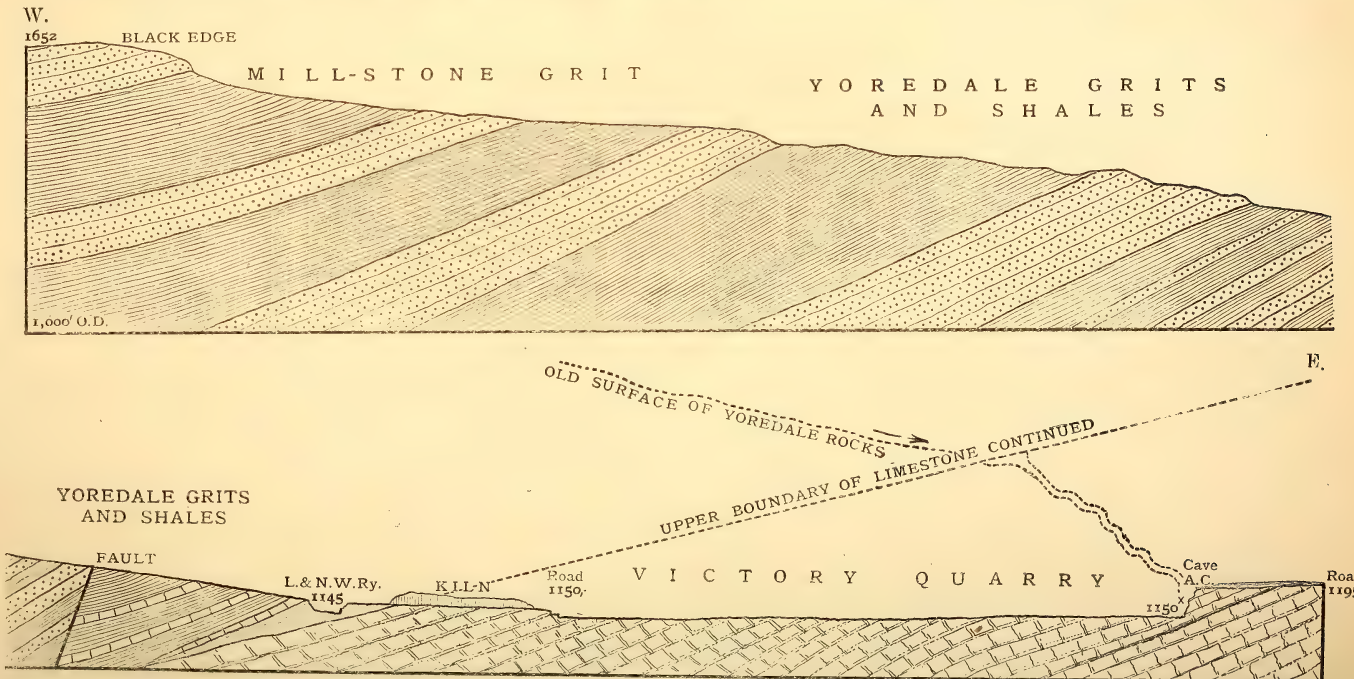
keeper of the Geological Department in the Manchester Museum, Owens College, who visited the quarry at times when I was unable to go thither, and recorded the discoveries.

II. The Present Physical Conditions of the District.

The Victory Quarry, Bibbington (see 6-inch Ordnance Map, Derbyshire, xv, N.W.), in which the discoveries were made, is about half a mile south of Doveholes railway-station and $2\frac{1}{2}$ miles north of Buxton. It has been gradually extended eastward from the Buxton road, in the direction of Longridge Lane and Higher Bibbington. The discoveries were made in working the eastern side, at the point A of the map and section (figs. 1 & 2, pp. 106 & 108). The Carboniferous Limestone here forms a rolling plateau, ranging from a height of 1100 to 1200 feet above Ordnance-datum, constituting the water-parting between the tributaries of the Goyt, flowing past Chapel-en-le-Frith northward and westward into the Mersey, and those flowing southward and eastward to join the Wye, the tributary of the Derwent that flows through Buxton. The quarry lies at a mean level of 1150 feet above Ordnance-datum on the western side, and on the eastern at 1187 feet, and has been carried down to about 45 feet below the surface of the limestone. It is on the divide between the Mersey and the Humber.

The Carboniferous Limestone consists of beds of remarkably pure limestone, dipping westward (see figs. 1 & 2) at an angle of 15° underneath the Yoredale Shales, close to the London & North-Western Railway. These black shales, with subordinate layers of limestone, are faulted against the Yoredale sandstones and grits, as shown in the above-mentioned figures. They form the base and middle of the range of hills extending southward to Buxton and beyond, the upper portion being composed of shales and sandstones of the Millstone-Grit Series, that rise in Black Edge (in the line of the section) to a height of 1652 feet. The drainage of their eastern slope passes downward until it reaches the limestone at its base. Here it sinks into the rock, through the many swallow-holes which mark the upper boundary of the Carboniferous Limestone. There are no surface-streams in the limestone in the immediate neighbourhood of the quarry, which, from its position on the divide, could not, under existing geographical conditions, receive the drainage of the range of hills to the west or from any other direction. The existence, however, of numerous 'swallets' on the divide, as well as in other portions of the Carboniferous Limestone, at a considerable distance from the impervious Yoredale Shales covering the limestone, proves that the limestone did in ancient times receive from the surface a considerable drainage which it no longer gets. Most of these 'swallets' are now filled with clay and loam, and some, as in the case of that at Windy Knoll, near Castleton, about 6 miles to the north-east, contain considerable quantities of the remains of Pleistocene mammalia.

Fig. 2.—*Horizontal section through the district, along the line marked on the map, fig. 1.* (*Scale: 12 inches = 1 mile.*)



III. The Conditions of the Discovery.

The cave (A of figs. 1–4) was discovered in the beginning of 1901, in the working of the quarry, and was fully exposed in the course of 1902. It was about 90 feet long, 15 feet high, and 4 feet broad at its northern end, descending slightly to the south as it contracted to a dead end (figs. 3 & 4, p. 110). It consisted of a large chamber and a small passage, both being eroded, as is usually the case, in a master-joint, traversing the quarry from top to bottom in a direction north 16° west. Its continuation to the north is obscured by a mass (B) of broken and acid-worn rock embedded in clay, which is at present slipping over the Carboniferous grey clay *b* (of fig. 3). In consequence of this a swallow-hole, *c* (of figs. 1, 2, & 3), has recently been exposed, measuring about 12 feet across, and filled with yellow loamy clay. It is probable that this will ultimately be proved to be connected with the cave, as the broken rock and clay are removed, although it is to the east of the line of the master-joint ruling the direction of the cave.

A photograph of the débris is reproduced in fig. 9, p. 124. The position of the cave in the eastern face of the quarry is shown in fig. 3, p. 110. The following strata occur here:—

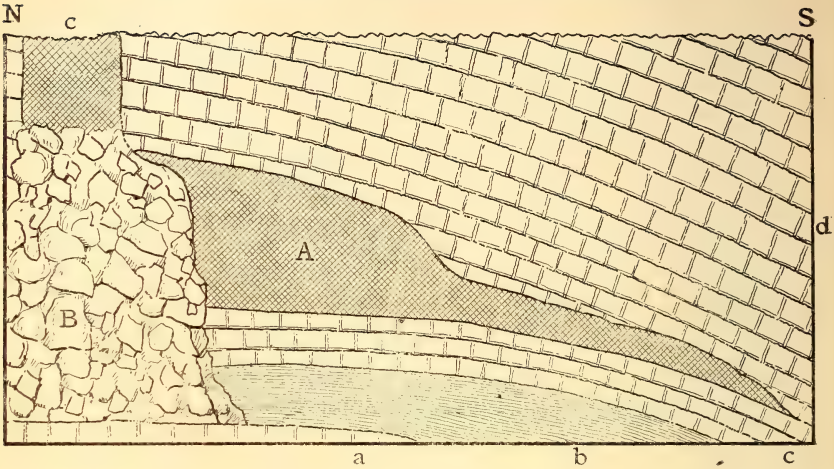
	Thickness in feet.
d. Grey limestone, in which the cave is hollowed ...	30
c. Grey limestone, forming the floor of the cave	9
b. Slate-coloured clay, with pyrite	9
a. Grey limestone	(?)

These rocks dip southward and westward. In the plan (fig. 4, p. 110) the winding of the cave along the line of the master-joint is worthy of notice.

The cave was filled with an horizontally stratified, yellowish-red clay, containing angular and rolled pebbles of limestone and a few pebbles of the sandstones of the Millstone-Grit and Yoredale Series. There were also pebbles of white vein-quartz, quartzite, and a brittle variety of elaterite. It contained, moreover, grains of sand and flakes of mica. Here and there, scattered irregularly through the mass, were mammalian bones and teeth, some rolled and in the condition of pebbles, others unworn and with sharp fractures; most are stained black and are highly mineralized, while others are stained red, and are not more mineralized than the remains usually found in Pleistocene caverns. Their general mineral condition bears a striking resemblance to that of the fossil mammals found in the Red and the Norwich Crags.

There can be little doubt that the contents of the cave have been introduced by water. In fig. 5 (p. 111) a section is given of the southern passage, narrowing towards its end, and only 2 feet across. It was completely filled with loamy red and yellow clay, horizontally stratified, and containing pebbles of limestone, Yoredale and Millstone-Grit sandstones, and bones and teeth, some in the condition of pebbles. Among the mammalian remains found in this place, the teeth of *Mastodon* and horse, and the metatarsals of deer may

Fig. 3.—*Section of the Pliocene cavern at Doveholes.*

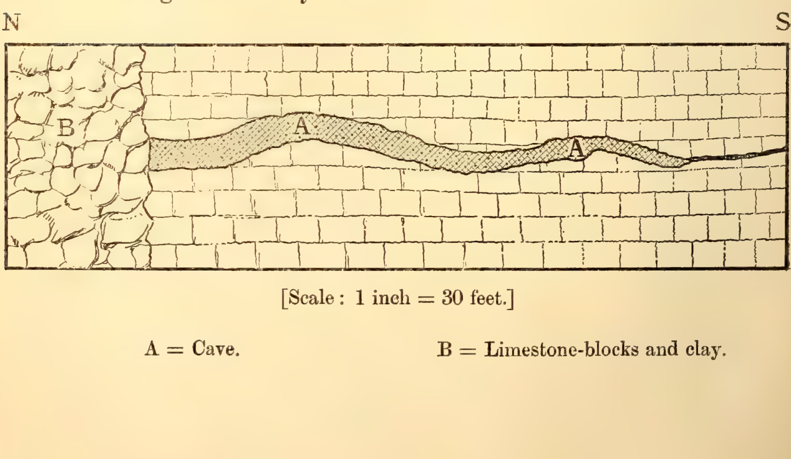


[Scale: 1 inch = 30 feet.]

A = Cave.
B = Limestone-blocks and clay.
C = Swallow-hole.

a = Grey limestone.
b = Slate-coloured clay.
c } = Grey limestone.
d }

Fig. 4.—*Plan of the Pliocene cavern at Doveholes.*

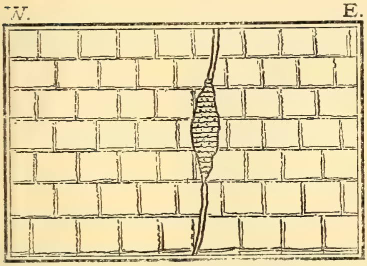


[Scale: 1 inch = 30 feet.]

A = Cave. B = Limestone-blocks and clay.

be mentioned. These are the unmistakable results of the passage of water from a higher level, collecting in its flow the stones and clay, and carrying along with it the bones and teeth of the mammalia into the lower chambers which it traversed. The operation is still going on in all swallow-holes that are now traversed by a stream, as, for example, in Helln Pot[1] (figs. 6 & 7, p. 112), one of the many potholes round Ingleborough, down which the surface-drainage of the Yoredale Series is carried to depths of more than 300 feet into the Carboniferous Limestone. It is probable that the cave A is not only connected with the swallow-hole *c*, but that the large blocks of limestone embedded in clay mark the line of a subterranean watercourse, which has been unroofed and destroyed in the general denudation of the surface.

Fig. 5.—*Section of passage in the cavern at Doveholes.*



[Scale: 1 inch = 20 feet.]

IV. The Fossil Mammalia.

The remains of the fossil mammalia described in the following pages are merely a few out of a large number which, according to the quarrymen, were discovered, and buried underneath a thick accumulation of débris before their importance was recognized. In the somewhat difficult task of their identification, I had the benefit at the British Museum (Natural History) of the aid of Dr. Smith Woodward, Dr. C. W. Andrews, and Dr. Forsyth Major, to whom I am indebted for several references to Continental literature. The carnivora will be considered first.

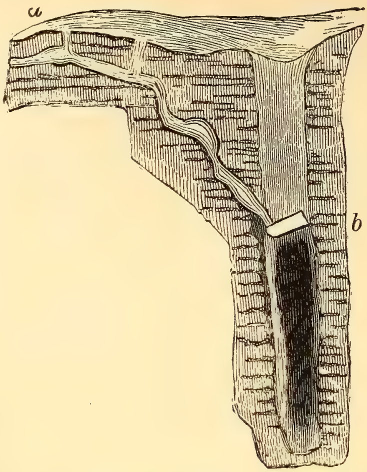
(a) *Machairodus crenatidens*, Fabrini.

The rare genus *Machairodus* is represented both by teeth and bones. Before, however, they can be identified it will be necessary to discuss the nomenclature of the Continental species. It is clear from the examination of the specimens in the Natural History Museum, and from the study of the essays on *Machairodus* published by Prof. Fabrini in 1890 and by Dr. Marcellin Boule in 1901,[2] that the *Machairodus cultridens* of Cuvier was founded on the mistaken association of the broad serrated canines of the *Machairodus aphanistus* of Kaup, from the Upper Miocene of Eppelsheim, with the species possessing smaller and non-serrated canines

[1] Dawkins, 'Cave-Hunting' 1874, pp. 41, 42.

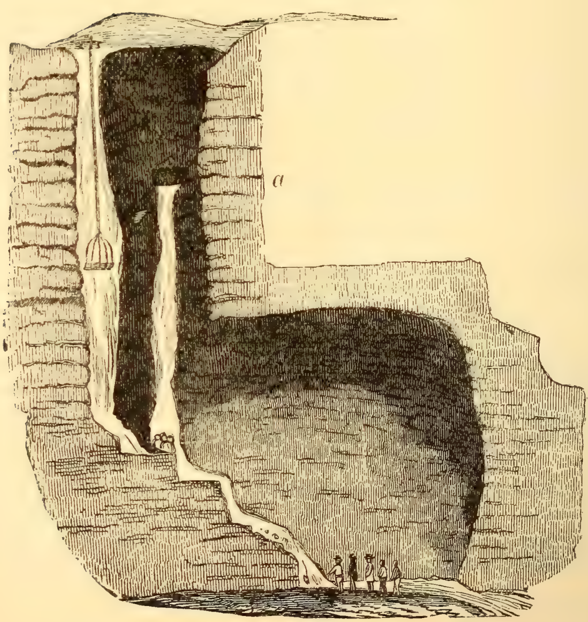
[2] Fabrini, Boll. R. Com. Geol. d'Italia, vol. xxi (1890) pp. 121, 161, & Boule, Bull. Soc. Géol. France, ser. 4, vol. i (1901) p. 551. In these essays the reader will find a masterly definition of the various European species of *Machairodus*.

Fig. 6.—*Diagram of Helln Pot and the Long Churn Cavern.*



[Reproduced from 'Cave-Hunting' 1874, p. 41.]
a = Long Churn Cavern. b = Helln Pot.

Fig. 7.—*Diagram of Helln Pot.*



[Reproduced from 'Cave-Hunting' 1874, p. 42.]
a = Long Churn Cavern.

found in the Pliocene strata of Auvergne and of the Val d'Arno. For the latter both Prof. Fabrini and Dr. Boule adopt the name *M. cultridens.* For the species with the larger and serrated canines from the Pliocene of the Val d'Arno, Prof. Fabrini proposes the name *M. crenatidens.* Dr. Boule accepts this definition, and points out that the species occurs in the Pliocene of Auvergne. The precise relation of this species to *M. latidens* of Owen from the Pleistocene caverns of Kent's Hole, Creswell, and of Montmaurin (Haute-Garonne) is uncertain. It is, however, probable that Dr. Boule is right in looking upon *M. crenatidens* as the Pliocene ancestor of *M. latidens*, the last survivor of this formidable type of lion in the Pleistocene age.

The larger of the three highly compressed imperfect upper canines found in the cavern is crenulated on the anterior and posterior cutting-edges (Pl. VIII, fig. 1). It is identical with the upper canine of *M. crenatidens,* as may be seen from the examination of Pl. VIII, fig. 1, which represents a photograph of the specimen laid over the outline of Fabrini's type-specimen from the Val d'Arno. It resembles *M. latidens* in its crenulation and broadness, and differs from *M. cultridens* in its larger size and crenulated edges.

A second and much worn fragment (Pl. IX, fig. 1) of the basal portion of the crown of an upper canine is smaller, and has the crenulations only represented on the inner edge by the faintest traces. It falls, however, well within the limits of *M. crenatidens*, as may be seen from fig. 1 (Pl. IX), superimposed upon the reversed outlines of Fabrini's type-specimen.

The third fragment is a portion of the fang referable to a tooth of the same species.

The variations in size of canines of Pliocene and Pleistocene species of *Machairodus* may be noted in the following table of measurements:—

Upper canines of *Machairodus*. (Measurements in millimetres.)	Total length.	Crown.	Fang.	Basal width of crown.	Basal breadth.
Upper canine. Cave at Doveholes (Pl. VIII, fig. 1)	...	...	103	34	14
Machairodus crenatidens, Fabr. (fig. Boule)	...	...	...	34	14
Do. do. (fig. Fabrini)	172	69	103	33	
M. latidens, Owen. Brit. Mus. (Nat. Hist.)	...	61	...	31	
Do. do. Geol. Soc. Lond.	...	...	82	30	
Do. do. Brit. Mus. (Nat. Hist.)	...	...	89	34	
Do. do. Coll. of Surgeons	...	69?	84	31	
M. cultridens. Val d'Arno	178	78	100	36	14
Do. Do.	170	100	75	23	13

Two highly compressed left upper carnassials (Pl. VIII, figs. 2 & 3) also belong to the same species, as may be seen by the following measurements:—

Left upper carnassials of *Machairodus*. (Measurements in millimetres.)		Antero-posterior measurement.	Antero-transverse.	Medio-transverse.	Postero-transverse.
M. crenatidens, pm 4.	Doveholes (Pl. VIII, fig. 2) ...	39	7	10	10
Do.	Do. (Pl. VIII, fig. 3) ...	39	6	10	10
Do.	Val d'Arno, Fabrini (Pl. VIII, fig. 4)	43			
M. cultridens,[1] pm 4.	Mont Perrier (Auvergne)	28	8	9	8

The specimens from Doveholes are slightly smaller than the type of Prof. Fabrini, from the Val d'Arno (Pl. VIII, fig. 4), but are too large to be assigned to *M. cultridens*. One (Pl. VIII, fig. 2) has an accessory cusp in front of the main conical cusp (*b*). All the three cusps (*b*, *a*, & *c*) are highly compressed parallel to the median line, and form one scissor-edge, divided into sections by deep vertical grooves. The accessory cusp seen in fig. 2 has probably been worn away from the anterior portion of fig. 3 (Pl. VIII). It is absent from Prof. Fabrini's type. The inner surfaces of these teeth are too much worn to be described.

Dr. Boule has called attention to the striking resemblance between the upper carnassials of *Machairodus* and the upper milk-carnassial of *Felis spelæa*. It may be added that the same resemblance runs through the whole adult dentition of *Machairodus*, when compared with the milk-dentition of *Felis spelæa*; as may be seen from the comparison of the specimens in the British Museum (Natural History) with pl. xiii of Dawkins's & Sanford's 'British Pleistocene Felidæ,' 1868 (Monogr. Palæont. Soc.).

The lower portion of the shaft of a right tibia (Pl. XI, fig. 1) corresponds in its main details with that of lion, and more particularly with a specimen of *Felis spelæa* from Sandford Hill Cave, figured by Mr. Ayshford Sanford and myself.[2] The measurements are as follows:—

[1] *M. meganthereon* of Gervais.

[2] Monogr. Palæont. Soc. vol. xxi, 1867 [1868] 'Brit. Pleistoc. Mammal. pt. ii, *elis spelæa*' p. 124.

Right tibiæ of Felidæ. (Measurements in millimetres.)	*Machairodus.* Doveholes.	*Felis spelæa.* Sandford Hill.	*F. leo.* Brit. Mus. 112.12.	*F. leo.* Brit. Mus. 112.	*F. leo.* Coll. Ayshford Sanford.
Minimum circumference............	102	122	77	82	84
Transverse measurement of distal articulation	50	77	53	49	59
Vertical measurement of distal articulation	33	49	31	31	33

The specimen of *Felis spelæa* from Sandford Hill, mentioned in the above table, is of unusual size. Another specimen from Bleadon Cave is much smaller, having a minimum circumference of 100 mm., and thus linking together the fossil with the living lions. The specimen from Doveholes falls naturally into this series, and may be referred to the only large feline species found in the cavern, the *Machairodus*. The distal articulation is slightly worn, and the outer edge which bore the facet for the fibula has disappeared. The bone bears unmistakable marks (*a* in fig. 1 of Pl. XI) of the teeth of *Hyæna*, probably of one or other of the species found along with *Machairodus* in Auvergne and Italy.

A right radius is also referable to the same species. It presents the characteristic rounded proximal articulation of *Felis spelæa* and the existing lion. It is, however, more slender than the former variety. It is 260 millimetres long, as compared with 323 and 354 of recent lion, in the University Museum, Oxford. Its distal articulation has been broken away.

A fragment of the shaft of a femur may also be referred to the same species. It also, like the tibia described above, bears unmistakable marks (*a*) of the teeth of *Hyæna*. (See Pl. XI, fig. 4.)

(b) *Hyæna.*

A fragment of left ulna, 111 millimetres long, without olecranon or distal articulation, has the deep fossa for the reception of the tuberosity just below the head of the radius, characteristic of the Hyænidæ. It is larger and stouter than the corresponding bones of *Hyæna spelæa*. It may probably be referred to one or other of the hyænas found along with *Machairodus* in the Pliocene of France and Italy, such as *H. arvernensis* of Croizet & Jobert. This bone bears the teeth-marks of *Hyæna*, which here, as in hyæna-dens of Pleistocene age, made no distinction between the bones of its own and of other species.

(c) *Mastodon arvernensis*, Croizet & Jobert.

It was the discovery of teeth of *Mastodon* that drew attention to the existence of the ossiferous cave at Doveholes. This mammal is represented by eighteen teeth, exclusive of fragments, and many broken and waterworn bones. These remains belong to the *Mastodon arvernensis* of Croizet & Jobert, defined by Falconer, and brought before the Geological Society in 1857.[1]

In that masterly paper Falconer, after the examination of most of the remains of *Mastodon* found on the Continent, assigned the molar teeth of this species to the tetralophodont, or four-ridged group, and proposed for it the following dental formula :—

$$\text{Deciduous dentition: } I\,\frac{1}{?},\quad Dm\,\frac{3}{3}.$$

$$\text{Permanent dentition: } I\,\frac{1}{0},\quad Pm\,\frac{2}{2},\quad M\,\frac{3}{3}.$$

He gave no description of the deciduous incisors or milk-tusks, and left the question open as to their presence in the lower jaw.

The four milk-tusks that I have examined present perfect tips, covered with strongly-wrinkled enamel, in various stages of wear. They are oval in section, and are remarkable for their small size. The smallest (Pl. IX, fig. 2) is 57 millimetres long, and 13 broad, and has a basal circumference of 40 mm. It consists of a grooved basal portion of dentine, with an obtusely-pointed spatulate tip of thick wrinkled enamel, convex on the outer side, and slightly tumid on the inner. The enamelled tip is 28 millimetres long, and 13 broad. This is a right lower milk-tooth of the deciduous series, and establishes the fact that the species possessed a pair of milk-tusks in the lower jaw.

The fragment of a larger specimen (Pl. VIII, fig. 5), 94 millimetres long, and 65 in circumference where the enamel ends, has an obtusely pointed tip, with the enamel nearly worn off by use. It is rounded on the outside, and flattened on the inside. A third (Pl. IX, fig. 3) has a remarkably thick and longitudinally grooved capping of enamel, which gradually diminishes in thickness as it passes down over the dentine. The length of the fragment is 94 millimetres, and the circumference at the broken margin of the enamel measures 70 millimetres. The strong grooves in the enamel are represented by shallower longitudinal grooves in the dentine, exposed by the removal of the enamel-covering. The unworn apex of the tusk is mammillated. The inner side is flattened oval, the outer strongly convex, a character presented by the preceding as well as the succeeding specimen. These characters are repeated in the fourth and largest of the series, which measures 120 millimetres in length, and 90 in basal circumference (see Pl. IX, fig. 4).

The three larger teeth are fragments of the milk-tusks of the upper

[1] Quart. Journ. Geol. Soc. vol. xiii, p. 307 & vol. xxi (1865) p. 253 ; see also Ch. Murchison, 'Palæont. Mems. of Hugh Falconer' vol. ii (1868) pp. 1–64.

jaw. The whole series has been hitherto unrecorded, and their discovery at Doveholes fills a blank in our knowledge of the dentition of the species.

The permanent tusks are represented by a few fragments, broken from originals of much larger diameter than the above. It is obvious, from Falconer's examination of the lower jaws of *Mastodon* in the Museums of Turin and Florence, that the adult *M. arvernensis* possessed no lower tusks.

The Molar Series.

The molars discovered at Doveholes, 21 in number, present all the characters of the tetralophodont section of the genus *Mastodon*. Their ridge-formula is as follows :—

$$\text{Milk-molars: } \frac{2+3+4}{2+3+4}, \quad \text{Pm } \frac{3+4}{3+4}, \quad \text{M } \frac{4+4+5}{4+4+5}.$$

Falconer only considered the milk- and the true molars, leaving out of account the two premolars, which have the ridge-formula of the penultimate and ultimate milk-molars that they displace.

The specific characters of the molar series of *M. arvernensis* are the strongly mammillated and wrinkled ridges (*a*) of the crown, and the development of wart-like secondary cusps (*b*), which block up the centres of the transverse valleys (*c*). The longitudinal depression in the centres of the transverse ridges (Pl. IX, fig. 5 & Pl. X, fig. 1) is marked by a zigzag line in the crowns. The cusps forming the transverse ridges (*a*) are arranged diagonally so as to form an alternate pattern with the secondary cusps (*b*), zigzagging from the front to the back of the crown. In all there is a strong front and back talon (*d*). The wrinkling and grooving of the enamel is more strongly marked in the milk- than in the true molars, and the upper may be distinguished from the lower series by their greater width.

The first milk-molar (dm 2) is probably represented by a stump too imperfect to be figured, which resembles that figured by Croizet & Jobert from Auvergne.[1] The upper penultimate milk-molar $\underline{\text{dm}}$ has not so far been discovered at Doveholes. Its dimensions are recorded in the table of measurements on p. 118, from the cast of a specimen from the Red Crag in the British Museum (Natural History). It is a perfect tooth, with the three ridges and talon before and behind.

The last upper milk-molar is represented at Doveholes by several teeth, of which two are figured in Pl. X, figs. 1 & 2. They have the characteristic four ridges (*a*) and two talons (*d*), which are united towards the central parts of the valleys of the unworn tooth (Pl. X, fig. 1) by flanking bosses of enamel. These, as may be seen in the figure, form a zigzag pattern on the surface

[1] 'Recherches sur les Ossemens Fossiles du Département du Puy de Dôme Pachydermes, pl. i, fig. 2 (4to, 1828).

of the crown, connecting the outer angle of the one ridge with the inner of the succeeding ridge. This tooth is only slightly worn on the surface of the two anterior ridges. The two fangs are imperfectly developed.

The second specimen (Pl. X, fig. 2) shows the alternate distribution of the cusps of the ridges in an older tooth, in which the enamel is worn almost down to the gums. It has been implanted in the jaw by two divergent short fangs, and has apparently been vertically succeeded by a premolar. These characters are reproduced in two other specimens worn down to the gums.

The lower milk-molars from Doveholes sufficiently perfect to be determined are 4 in number. The two-ridged milk-molar 2 is too imperfect to be figured. It consists of portions of the front talon and front ridge, and of the hind ridge supported by a long fang.

The next, or the penultimate lower milk-molar 3, has not yet been found at Doveholes. It is in the Manchester Museum, Owens College, and is reproduced here (Pl. IX, fig. 5) because it has not been figured before, and because it passed through the hands of Dr. Falconer. It consists of three ridges composed of diagonal cusps and anterior and posterior talons. It came from the Norfolk Crag, and was given to me by the Rev. S. W. King, of Saxlingham.

Three worn crowns represent milk-molar 4. The most perfect of these has the usual characteristic pattern and ridge-formula. The figured specimen was discovered by Master Hick (Pl. X, fig. 3). It is distinguished from the corresponding upper milk-molar by its narrowness. It is supported by two strong divergent fangs, the anterior of which is broken away. The rest are more worn, and deserve no further details.

The following table embodies the measurements of the milk-teeth from Doveholes, along with those of other specimens :—

Milk-molars of *Mastodon arvernensis*. (Measurements in millimetres.)		Antero-posterior.	Antero-transverse.	Medio-transverse.	Postero-transverse.
Dm 2.	Upper, Doveholes. Manchester Museum	24	15	...	18
Dm 3.	Upper, cast, Red Crag, Suffolk. Brit. Mus. ...	50	34	36	34
Dm 4.	Upper, Doveholes. Coll. Hick	77	44	47	44
Dm 4.	Upper, Doveholes. Manch. Mus.	77	44	49	44
Dm 3.	Lower left, Red Crag, Norfolk. Manch. Mus.	52	26	31	33
Dm 4.	Lower right, Doveholes. Coll. Hick.	76	34	38	40
Dm 4.	Lower left, Doveholes. Manch. Mus.	77	34	39	41
Dm 4.	Lower left, Red Crag, Felixstowe. Brit. Mus.	83	35	40	44

The true molars of *Mastodon* from Doveholes consist of two fragments of molar 1 of the lower jaw, and a perfect true molar 2. Their measurements are recorded in the accompanying table, along with those of other teeth of the same species with which they have been compared. The crowns of all these teeth present the same strong development of bosses of enamel which block up the interspaces between the ridges, the ridges themselves being formed of alternating cusps. The specimen figured (Pl. XI, fig. 2) is an unworn crown covered with cement, with the four ridges and the usual talons of the second true molar $\overline{\text{m2}}$.

The measurements of the true molars are as follows:—

	True molars of *Mastodon arvernensis*. (Measurements in millimetres.)	Antero-posterior.	Antero-transverse.	Medio-transverse.	Postero-transverse.
M 1.	Upper right, Norwich Crag, Thorpe. Jermyn Street	95	54	58	52
M 2.	Upper left, Red Crag, Suffolk. Manch. Mus....	104	52	58	57
M 3.	Upper right, Red Crag, Woodbridge. Brit. Mus.	182	0	72	47
M 3.	....	175	72	74	54
M 1.	Lower left, Red Crag. Felixstowe. Brit. Mus.	111	46	54	54
M 1.	Lower, Doveholes. Salt Coll., Buxton...........	...	46	49	
M 1.	....	...	44	44	
M 2.	Lower left, Doveholes. Manch. Mus.	124	52	58	56
M 3.	Lower left, Red Crag, Felixstowe. Brit. Mus. ...	186	82	82	51
M 3.	Lower right, Red Crag, Foxhall. Brit. Mus. ...	235	86	89	52

There are among the fragments of bones many which are assignable to *Mastodon*, such as an ulna and radius, and probably also a gnawed humerus (Pl. XI, fig. 3), all belonging to calves.

(d) *Elephas meridionalis*, Nesti.

A much-worn fragment of molar consisting of the base of the anterior portion of a tooth, with one nearly perfect and portions of the two adjacent plates (Pl. X, fig. 4), belongs to *Elephas meridionalis*. It has the thick rugose plicated enamel (*a*), and the broad plates of dentine (*b*) characteristic of that species, agreeing in these respects with several specimens, worn to the same extent, in the British Museum (Natural History). In this figure *c* represents the cement.

(e) *Rhinoceros etruscus*, Falconer.

The genus *Rhinoceros* is represented by two fragments of waterworn molars. One of these, consisting of the external lamina of

the first right upper molar, exhibits the characters of the *Rhinoceros etruscus* of Falconer, which I defined in my paper brought before the Society in 1868.[1] It is so like the corresponding part of a left upper molar from the Val d'Arno in the Natural History Museum, figured in the Quarterly Journal, vol. xxiv (1868) pl. viii, fig. 3 *b*, that it is unnecessary to reproduce it.

The second fragment consists of a crown of a lower true molar, so worn that it has lost its distinctive characters, as is the case indeed with many remains of *Rhinoceros* from the Crag which are, as a rule, ascribed to the Miocene *Rh. Schleiermacheri* of Kaup. It may, with high probability, be referred to the same species as the upper molar.

(f) *Equus Stenonis*, Nesti.

The horse is represented by three upper molars and one lower. The most perfect of these (Pl. XII, figs. 1–3) has all the characters which have been shown by Dr. Boule to mark off *Equus Stenonis* from *E. caballus*. They consist of the small section of the columella (*a*) in the grinding-surface (Pl. XII, fig. 1), as compared with its large extent in *Equus caballus* (Pl. XII, fig. 4) from the Creswell caves, and in the narrowness and sharp definition of the two ridges or costæ (Pl. XII, figs. 2 & 3) traversing the external lamina of the tooth, when contrasted with the broadness and flatness, and sometimes the grooving of the corresponding portion in the latter species. On the inside of the tooth the columella is narrower than in *E. caballus* (Pl. XII, figs. 5 & 6). These points of difference are comparatively small, but they are observed in the equine teeth found in the Pliocene of Auvergne and of the Val d'Arno, as well as in the teeth assigned to this species by Mr. E. T. Newton [2] from the Forest-Bed of Norfolk.

A lower true molar (m 3) and two fragments of upper molars present no points worthy of remark. They probably belong to the same species. Dr. Boule [3] recognizes intermediate forms in the Upper Pliocene or early Pleistocene strata of Solilhac. His view that the Pliocene *Equus Stenonis* is the ancestor of the Pleistocene *E. caballus* is probably true.

(g) *Cervus etueriarum (?)* Croizet & Jobert.

The Cervidæ are represented at Doveholes by numerous bones, all more or less fragmentary, and therefore very difficult to determine specifically. They belong, however, to one or other of the many species of Pliocene deer, and agree more particularly with *Cervus etueriarum* of Croizet & Jobert = *C. peyrollensis* of Bravard, from

[1] Quart. Journ. Geol. Soc. vol. xxiv, p. 207.

[2] 'The Vertebrata of the Forest-Bed Series' Mem. Geol. Surv. (1882) pl. vii.

[3] Bull. Soc. Géol. France, ser. 3, vol. xxvii (1900) pp. 531–42.

Peyrolles. Their measurements, as may be seen in the following table, come very close to those of the latter species in the British Museum (Natural History). They may, therefore, be provisionally assigned to that species.

Measurements (in millimetres) of *Cervus etueriarum* (?) and *C. peyrollensis.*		Length.	Minimum circumference.	Transverse measurement of proximal articulation.	Vertical measurement of proximal articulation.	Transverse measurement of distal articulation.	Vertical measurement of distal articulation.
Scapula	Doveholes.	...	59	0	22		
Humerus ...		...	57	0	0	27	50
Humerus ...		...	77	...	...	40	65
Metacarpal ...		...	70				
Tibia		...	73+	0	0	38	18
Tibia		...	65	0	0	33	13
Metatarsal ...		220	44	20	20	24	
Metatarsal ...		...	49	18	20		
Metatarsal ...		...	50				
Scapula	Peyrolles, British Museum (Natural History).	...	...	30	28		
Humerus ...		...	65	0	0	35	50
Humerus ...		...	60	0	0	32	50
Tibia		270	68	0	0	33	17
Tibia		...	68	36	40	33	15
Metatarsal ...		...	...	22	23		
Metatarsal ...		...	51	24	24		

Cervus etueriarum, as I have already shown in a paper on the 'History of the Deer of the European Miocene & Pliocene Strata,' brought before this Society in 1877,[1] is closely allied to the axis, chetul, or spotted deer of India. It occurs in the Upper Pliocene, both of Auvergne and of the Val d'Arno.

V. The Mammalia of Upper Pliocene Age.

The range in space and in time of the mammalia just described leaves no room for doubting the geological age of the deposit in which they rest. All the species occur in the river-deposits of well-defined Upper Pliocene age in Auvergne and the Val d'Arno, and may be studied in the Museums of France and Italy. In Britain, *Mastodon arvernensis*, *Elephas meridionalis*, *Equus Stenonis*, and *Rhinoceros etruscus* (?) [2] are found in the Red Crag.

The distribution of the whole group in Britain and on the Continent is shown in the following table:—

[1] Quart. Journ. Geol. Soc. vol. xxxiv (1878) p. 410.

[2] In my opinion this is represented, in part at least, by '*Rh. Schleiermacheri*' of the Red Crag.

RANGE OF MAMMALIA IN BRITAIN AND THE CONTINENT.

Cavern at Doveholes.	Upper Pliocene Strata. Auvergne.	Val d'Arno.	Red Crag.	Pleistocene Forest-Bed.
Machairodus crenatidens	*	*	..	
Hyæna	*	*		
Mastodon arvernensis	*	*	*	
Elephas meridionalis	*	*	*	*
Rhinoceros etruscus	*	*	?	*
Equus Stenonis	*	*	*	*
Cervus etueriarum (?)	*	*	?	

The mammalia of Doveholes belong therefore to the *Mastodon-arvernensis* fauna of the British and Continental Pliocene strata, and are clearly defined from that of the Pleistocene age, not only by the presence of characteristic Pliocene forms, but by the absence of those which came into Europe at the beginning of the Pleistocene, such as the cave-bear, the mammoth, the woolly rhinoceros, and the living Palæarctic species. In the Forest-Bed this latter group is associated with species which survived the change in environment that took place at the close of the Pliocene age. There is no such association of Pliocene with later types to be found in the Upper Pliocene deposits of France and Germany, as may be seen from the lists published in Appendix III of my work on 'Early Man in Britain,' and in those of Dr. Forsyth Major, published in the Quarterly Journal of this Society. The *Elephas meridionalis*, *Rhinoceros etruscus*, and *Equus Stenonis* of the cave at Doveholes, are among these survivors in the Forest-Bed; but it does not, therefore, follow that they establish a correlation between the cave at Doveholes and the Forest-Bed, which contains a fauna not as yet found anywhere in association with *Mastodon arvernensis*. The presence in this fauna of cave-bear, mammoth, Irish elk, stag, roe, urus, musk-sheep, horse, and wild boar, prevents me from accepting the view of Mr. E. T. Newton and Mr. Clement Reid, that the Forest-Bed belongs to the same period as the Upper Pliocene Series of Auvergne and the Val d'Arno.[1] It belongs, as Lyell pointed out in his 'Antiquity of Man,' in 1863 (pp. 211 *et seqq.*), to a later period—when the mammalia were migrating from Northern Asia into Europe in the pre-Glacial or early stage of the Pleistocene Period.[2]

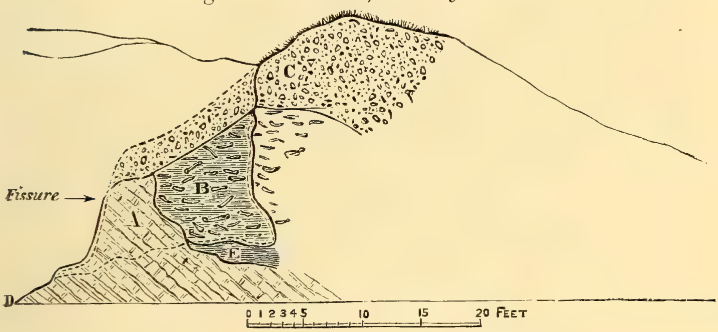
[1] Clement Reid, 'Pliocene Deposits of Britain' Mem. Geol. Surv. (1890) pp. 222–23.

[2] This question has been fully discussed in my work on 'Early Man in Britain' 1880, chapters v & vi.

VI. The Mammalia introduced by Water from a Hyæna-Den at a Higher Level.

In dealing with the remains of the fossil mammalia, we have noted the presence of gnawed bones exhibiting the characteristic teeth-marks of *Hyæna*. We have also recorded the ulna of that cave-haunting animal. The tooth-marked surface of the tibia of *Machairodus* (Pl. XI, fig. 1 *a*), and the gnawed shaft of a femur with one end gnawed off and the other broken (Pl. XI, fig. 4 *a*), prove that even this formidable carnivore is to be reckoned among its prey. A fragment of a humerus, probably belonging to a calf-*Mastodon*, is not only tooth-marked, but gnawed to the same shape as the corresponding bones of woolly rhinoceros in hyæna-dens of Pleistocene age (Pl. XI, fig. 3). The preponderance in the cave at Doveholes of the remains of young, as compared with old, teeth of *Mastodon*, is exactly that which is noticeable, in the case of calf and

Fig. 8.—*Section of Windy Knoll.*



A = Rock. C = Rubbish.
B = Ossiferous loam, etc. D = Floor of quarry.
E = Yellowish débris.

[The portion excavated is enclosed with a dotted line.]

adult mammoths, in all the hyæna-dens, as for example Kirkdale, Wookey Hole, and those of Creswell Crags. Had the remains belonged to animals which had been drowned, and swept in from the surface, they would have been in a condition more or less perfect, such as those filling the mouth of a swallow-hole at Windy Knoll (fig. 8), described in Quart. Journ. Geol. Soc. vol. xxxi (1875) p. 246, & vol. xxxiii (1877) p. 724. Here the remains of bison, grizzly bears, foxes, and wolves are sufficiently complete to allow, in some cases, of the reconstruction of perfect limbs. It may further be remarked that this latter accumulation, like that of Doveholes, is in the limestone, and at a little distance from the Yoredale Series, and so placed on a divide that it would be impossible, under present conditions, for the clay and loam in it to have been washed into it from the adjacent slopes of Yoredale Shale. The perfect bones of a rhinoceros,

Fig. 9.—*Photograph of clay, with blocks of the limestone B of figs. 1, 2, & 3, at the northern end of the cave.*

[The two spades mark the place of the ossiferous clay.]

found in the cave at Wirksworth, also contrast with those under consideration. There, as Buckland pointed out in his 'Reliquiæ Diluvianæ,' the animal had undoubtedly fallen down an open swallow-hole, and was buried in the clay and loam introduced by a stream flowing into it in ancient times.

From all these facts it may be concluded that the fragmentary remains in the cave at Doveholes were derived from a den of hyænas belonging to the Pliocene age.

It is, however, obvious that they were not introduced by those animals into the chambers where they were discovered, but that they were conveyed from a higher level into it by water. My reading of the riddle is simply that they were originally accumulated in a hyæna-den open to the surface, and that afterwards they were conveyed into lower chambers, where they were protected by the limestone from the denudation which has destroyed nearly all traces of the original surface, leaving the cave A (figs. 2, 3, & 4, pp. 108, 110), the mass of clayey débris B, and the swallow-hole C, as the only signs of the former existence of streams plunging into the rock at this place. The blocks of limestone embedded in clay, shown in the photograph (fig. 9, p. 124), obscuring the northern end of the cave, appear to me to be the ruins of a cave or of a ravine which had formerly been filled with clay, like those portions of the cave which we examined. The presence of the clay in which they are embedded cannot be explained by the slip which is now going on, resulting from the working of the quarry down to the layer of Carboniferous clay (figs. 2 & 3, p. 110). This occurs at a depth of 9 feet below the floor of the cave: it could not have come from anywhere, except from a higher level.

Helln Pot (figs. 6 & 7, p. 112), and the associated caves opening upon it, on the flanks of Ingleborough, illustrate the probable conditions under which the contents were introduced. Here the surface-waters passing over the Yoredale Shales of the upper slopes pass into a series of caves, and ultimately plunge into the great pothole, at various levels beneath the surface, carrying the drainage of the Yoredale Shales more than 300 feet deep into the rock. At the present time the passages to still lower levels are open, and consequently there is no deposit of clay in the great chamber some 300 feet below the surface, explored by Mr. John Birkbeck, myself, and others in 1870.[1] There are, however, blocks of stone, great and small, which have tumbled from the roof and sides. Had the accessible caves at the surface, as for example the Long Churn Cavern (figs. 6 & 7 *a*), been haunted by hyænas, the remains of the victims would from time to time have been swept down into the chasm, and if the water-passage became blocked, would have accumulated in the great chamber. In other words, we should have conditions similar to those under which the cave at Doveholes was probably filled with its contents.

[1] Dawkins, 'Cave-Hunting' 1874, pp. 41–44.

VII. The Denudation of the District since the Pliocene Age.

I pass now to the question of the denudation of the district since the cave was filled in the Upper Pliocene Age. In my work on 'Early Man in Britain' (p. 144), I pointed out that the absence of Pliocene caves in Europe was due to the fact that the whole of the Pliocene surface had been denuded away from the areas of limestone, which then, as now, were the dens of wild beasts; and that the caves and their contents of all periods older than the Pleistocene had been destroyed. The solitary exception to this generalization is the Pliocene cave at Doveholes, which was far enough from the surface to escape the common destruction. It is possible to ascertain in this case the minimum amount of denudation of the limestone, since the stream introduced the clay, loam, and pebbles from the slopes of the hills of Yoredale Shale, etc. and Millstone Grits to the west. Under the existing conditions no water is delivered into the area of the Victory Quarry from the west. Had there been drainage in this direction, it would have disappeared in the limestone before it reached the quarry. At the time when the cave was filled, it obviously received the drainage of the rocks which now form the hills, and must therefore have been at the bottom of a valley, instead of being on a water-parting. I have attempted to restore this ancient land-surface in the dotted lines of fig. 2 (p. 108), in which I have carried the lower boundary of the Yoredale rocks along the plane of dip to a sufficient height to command the cave. If this be taken as an approximation to the truth, it will involve the lowering of the general surface of the limestone by denudation to the extent of at least 330 feet, since the time when the cave was filled with its present contents. From the wide range of swallow-holes over the plateau of limestone, in places where streams would be impossible under existing conditions, it may be inferred that the denudation affected the whole surface of this district. It would be sufficient to destroy the ravine formed by the stream above the bone-cave at Doveholes, and all the caves accessible to the Upper Pliocene mammalia, both in this district and elsewhere.

VIII. The Geography of Britain in the Upper Pliocene Age.

We must now consider the geography of Britain during the Upper Pliocene Age. The map published in 'Early Man in Britain' in 1880 (p. 73) has been but slightly modified by later discoveries. Mr. Jamieson[1] pointed out in 1882 that the Marine Crag of Aberdeen is merely a remanié deposit, derived from the Red Crag, and of Pliocene age, and that, consequently, there is no evidence that the Upper Pliocene coast-line touched any part of Scotland. Mr. Clement Reid,[2] in his admirable work already cited, has collected together evidence to show that the Lower Pliocene sea extended southward, so

[1] Quart. Journ. Geol. Soc. vol. xxxviii, p. 145.
[2] 'Pliocene Deposits of Britain' Mem. Geol. Surv. (1890) map, pl. i.

as to cover the south-eastern corner of Kent and the region of Calais. He has also proved that the sea extended at this stage in the Pliocene from Normandy (Cotentin) to Cornwall (St. Erth), leaving a barrier of land between these two areas which would allow of the migration of the mammalia. He leaves the distribution of land and water in

Fig. 10.—[The heavy black line marks the Pliocene shore.]

the British Isles in the Upper Pliocene Age practically as it was before. In the accompanying map (fig. 10) I have reproduced that of 1880 with the necessary correction.

The margin of the Upper Pliocene sea, on the eastern side of Britain, is marked by the marine Upper Crag-deposits of Norfolk,

Suffolk, and Essex. It is proved, by the presence of the northern mollusca, to have been continuous with the Arctic Sea, and by the angular and sharp-edged flints, observed by Lyell in the Red Crag, to have been occupied sometimes by floating ice. The rivers opening into it carried down materials which were derived, as the late Sir Joseph Prestwich and Mr. Jukes-Browne[1] pointed out, from the west. A drainage-area of Carboniferous Limestone, Lias, and Chalk contributed to the materials forming the Red Crag. In the Red Crag of Sutton the Oolite and the Lower Greensand also are represented.[2]

In other words, the rivers flowed eastward from the Carboniferous rocks of the Pennine Chain and its southerly continuation, through Charnwood Forest, and had drainage-areas similar to those of the rivers thrown off westward from that axis.

The depression of the area of the North Sea, which allowed the Arctic mollusca to migrate as far south as Essex, renders it probable that the ancient barrier of land, in the Eocene (Oligocene) and Miocene Periods, which extended from the North of Scotland to Iceland and Greenland, was submerged, and that the waters of the Atlantic were in free communication with those of the Arctic Sea west and north of the line of sharp depression marked by the 100-fathom line, rapidly descending to depths of more than 1000 fathoms. The absence of marine deposits of Upper Pliocene age on the western side of Britain may be accounted for by this low area (now submerged) being then the coast-line, and the whole of the rest of the British Isles being dry land, with the main watersheds and river-valleys very much as they are now, although denuded, in the area which still remains above the sea. In this case the western equivalents of the Pliocene Crags in the east would be submerged.

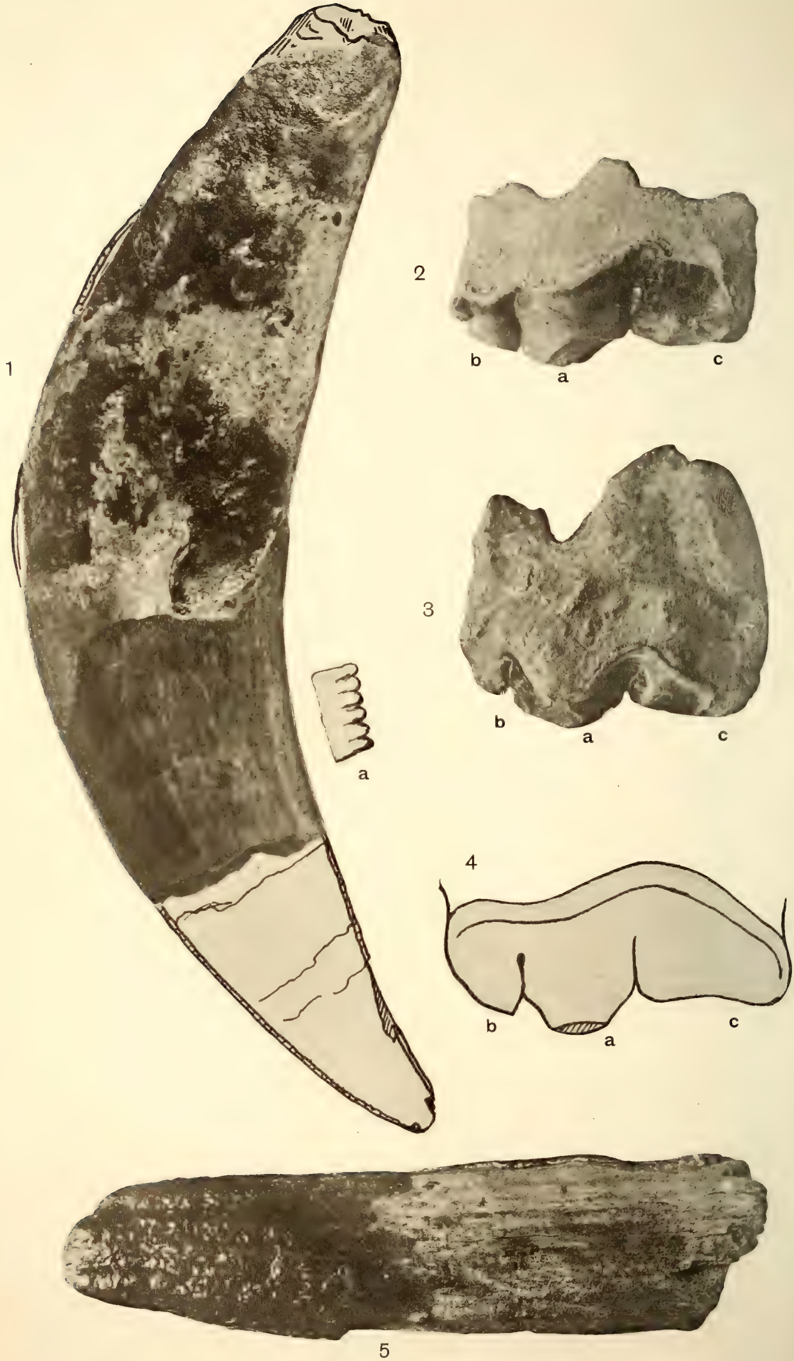
Under conditions such as these, there would be no physical barrier to the migration of the Upper Pliocene mammalia from Auvergne, over the plains of France, and across the valley of the English Channel, into Britain, and, it may be added, into Ireland. The discovery of a few of them in a bone-cave in Derbyshire is to be looked upon as a proof of the range of the whole fauna over the north-western region. Their route northward through France is marked by the remains of *Elephas meridionalis* and *Rhinoceros etruscus* in the gravel-pits of St. Prest, near Chartres.[3] In the South of England one of them *(Elephas meridionalis)* has been discovered in a gravel-bed at Dewlish in Dorset.[4] With this exception, they have hitherto been found in Britain only at the mouth of the rivers that opened into the North Sea of the Upper Pliocene age. The discovery at Doveholes establishes their presence on the uplands, on the backbone of England, drained by these very rivers.

[1] 'Building of the British Isles' 2nd ed. (1892) p. 358.

[2] Prestwich, Quart. Journ. Geol. Soc. vol. xxvii (1871) p. 476; Jukes-Browne, *op. supra cit.* p. 357.

[3] I obtained this species of *Rhinoceros* from the gravel of St. Prest myself.

[4] C. Reid, 'Pliocene Deposits of Britain' Mem. Geol. Surv. (1890) p. 207.



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Machairodus crenatidens and Mastodon arvernensis.

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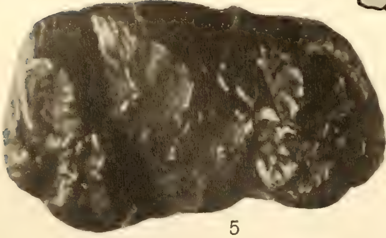

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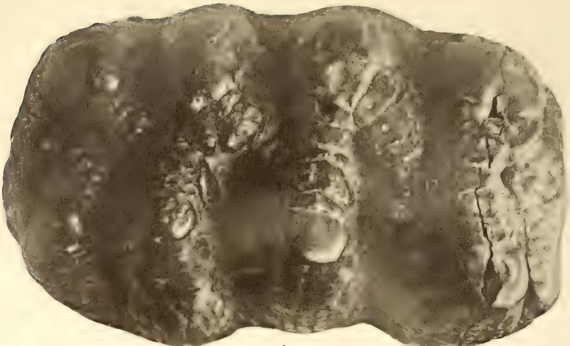
Bemrose Ltd., Collo.

Machairodus crenatidens and Mastodon arvernensis.



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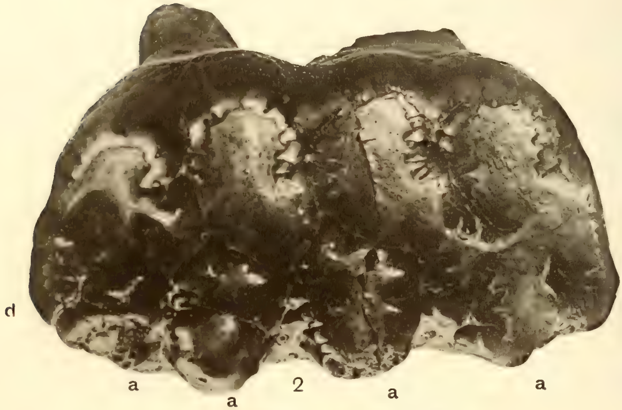

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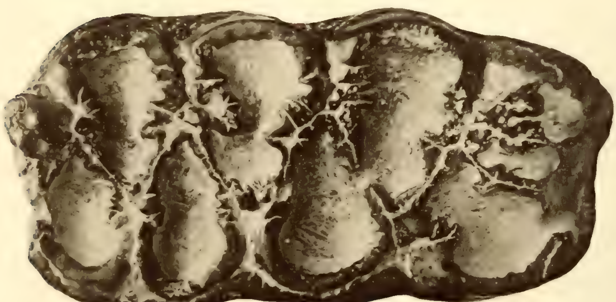

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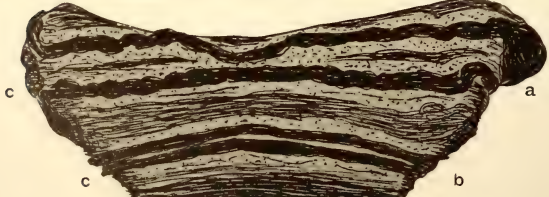

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Bemrose Ltd., Collo.

MASTODON ARVERNENSIS AND ELEPHAS MERIDIONALIS.

2

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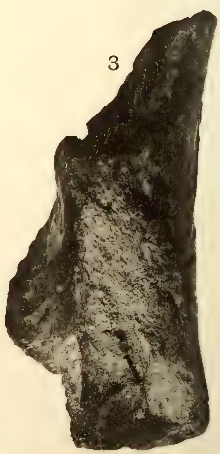

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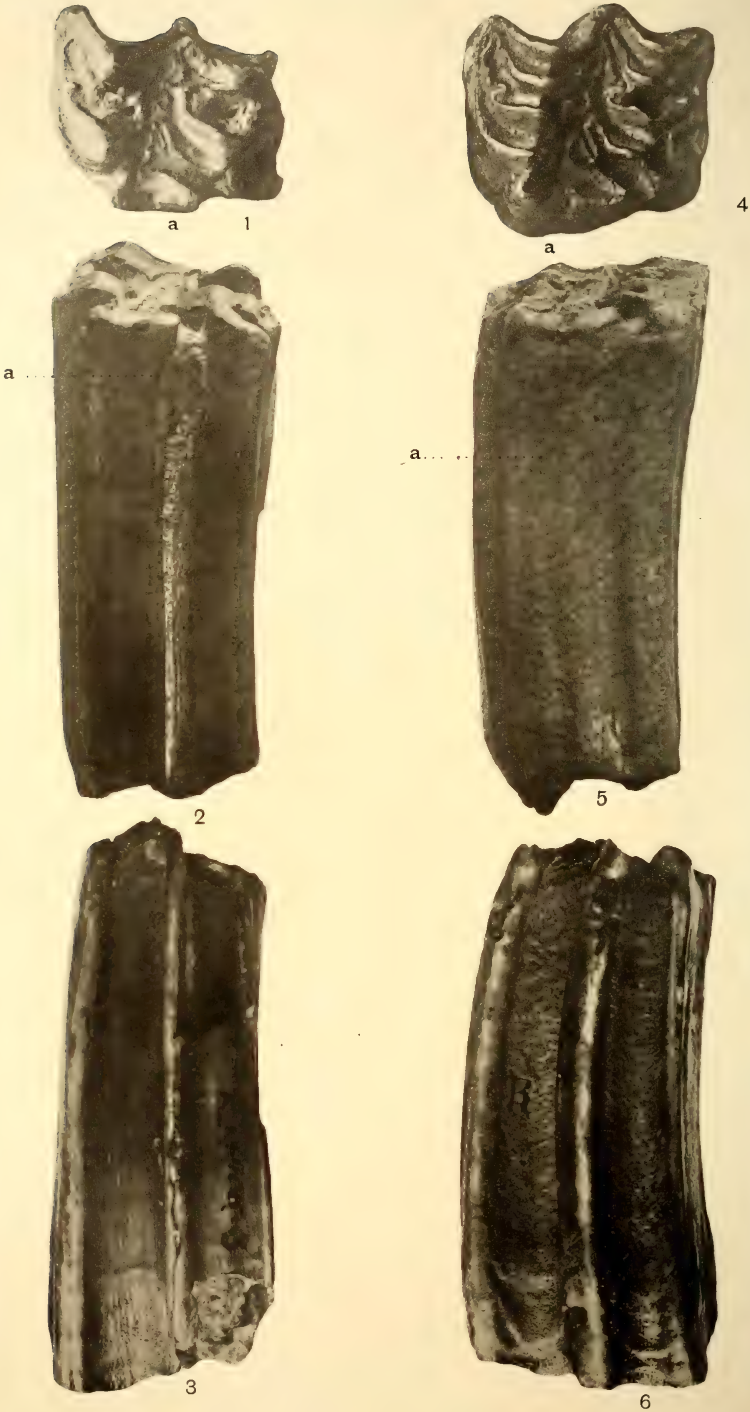
MACHAIRODUS CRENATIDENS AND MASTODON ARVERNENSIS.



Bemrose Ltd., Collo.

Equus Stenonis and Equus caballus.

IX. Conclusion.

It remains now to sum up the general results of this discovery. It has added one species, *Machairodus crenatidens*, to the Upper Pliocene fauna of Britain, leaving out of account *Cervus étueriarum*. It has not added to our knowledge of the distribution of Upper Pliocene land and sea, but it has confirmed the conclusions arrived at on other evidence. It is the only Pliocene cave yet discovered in Europe, and is the only evidence as yet available of the existence of the Upper Pliocene bone-caves, which, from the nature of the case, must have been as abundant in Europe as those of the succeeding Pleistocene Age. From this point of view it offers a striking illustration of the fragmentary nature of the geological record, and of the general effect of denudation on the surface of the land.

EXPLANATION OF PLATES VIII–XII.

[All the specimens figured are from Doveholes, unless otherwise stated, and are deposited in the Manchester Museum, Owens College.]

Plate VIII.

Fig. 1. Upper canine of *Machairodus crenatidens*, nat. size: a = serration magnified.

Figs. 2 & 3. Left upper carnassials of *M. crenatidens*, nat. size.

Fig. 4. Left upper carnassials of *M. crenatidens*, from the Val d'Arno: nat. size.

5. Upper milk-tusk of *Mastodon arvernensis*, nat. size.

Plate IX.

Fig. 1. Upper canine of *Machairodus crenatidens*, nat. size.

2. Outer view of lower milk-tusk of *Mastodon arvernensis*, nat. size.
3. Outer view of upper milk-tusk of *M. arvernensis*, nat. size.
4. Outer view of upper milk-tusk of *M. arvernensis*, nat. size.
5. Lower milk-molar 3 of *M. arvernensis*, from the Crag of Norfolk: nat. size.

Plate X.

Fig. 1. Last upper milk-molar of *Mastodon arvernensis*, unworn, nat. size.

2. Last upper milk-molar of *M. arvernensis*, worn, nat. size. (d = talon.)
3. Lower milk-molar of *M. arvernensis*, nat. size.
4. Section of molar of *Elephas meridionalis*, nat. size. (a = enamel; b = dentine; c = cement.)

Plate XI.

Fig. 1. Tibia of *Machairodus crenatidens*, $\frac{1}{2}$ nat. size. (a, a = tooth-marks.)

2. Left lower true molar 2 of *Mastodon arvernensis*, $\frac{1}{2}$ nat. size. (a = ridges; b = secondary cusps; c = valleys; d = talon.)
3. Humerus of *Mastodon arvernensis (?)*, gnawed by hyæna: $\frac{1}{2}$ nat. size.
4. Femur of *Machairodus crenatidens*, gnawed by hyæna: $\frac{1}{2}$ nat. size.

Plate XII.

Figs. 1, 2 & 3. Upper molar of *Equus Stenonis*, nat. size.

4, 5 & 6. Upper molar of *E. caballus*, from the Pleistocene of Creswell Crags, nat. size. (a = columella.)

Discussion.

Dr. Forsyth Major agreed with the Author that the mammalia were of Upper Pliocene age, and also that the finding of mammalia of this geological horizon in a cave was, up to the present, quite an unique occurrence, although other supposed instances had been mentioned, as, for example, the *Macacus suevicus*, which was found in a cave of the Schwäbische Alb. However, the association of a monkey with the reindeer and other Arctic mammalia need not be a matter of surprise, since there were other instances of monkeys having been found in Pleistocene deposits, namely, the *Macacus pliocænus* from the brickearth of Grays (Essex), and another species in caves of Southern France, and since some species of Old-World monkeys (*Semnopithecus*, *Macacus*, *Theropithecus*, *Colobus*) were known to live at heights of 10,000 to over 13,000 feet.

It had been repeatedly asserted that the mammalian remains from the breccias and caves of Sardinia and Corsica were of Tertiary age; if this were so, there would be no Pleistocene mammals at all in those islands. As a matter of fact, most of these fossils were more nearly related to Continental Pliocene and Miocene mammals than to members of the Pleistocene European fauna; the explanation of this relation was that the former connections between the islands and the continent—during part or the whole of the Tertiary Era—must have been severed before, or at the beginning of Pleistocene times. It was quite possible that mammals of Eocene, Oligocene, Miocene, and Pliocene ages found in rock-fissures, might in many cases have been deposited originally in a cave.

The association of *Mastodon arvernensis* with *Elephas meridionalis* was an undoubted, although by no means a frequent, occurrence in the Val d'Arno. The difference in the structure of their molars was proof of a difference in their diet, and this accounted for their not being as a rule found associated together.

Prof. Seeley said that, while the occurrence of *Mastodon arvernensis* in a cavern was a new fact of first-rate importance in Tertiary geology, the evidence for the occurrence of *Elephas meridionalis* was such that the tooth might perhaps pertain to *E. primigenius*. *Machairodus* was a fossil of Pleistocene caverns. The difference of this fauna from that of newer caverns was coloured by the presence of the Crag fossil *Mastodon arvernensis*; yet that species might well have lived to a later time in the high land of Derbyshire. The remains were in part rolled, broken, and manifestly transported by water; so that it might be that the living animals had neither been carried by floods, nor fallen through the roof, but had been derived from a local deposit, which was removed in the denudation associated with the Glacial Period. While the fauna of this cave was quite unlike that of newer caverns, the evidence for the Pliocene age of the deposit was not so certain as was to be desired in establishing a new truth.

Mr. E. T. Newton saw no reason for doubting the Pliocene age of the series of mammalian remains. Our surprise was not so much

at the finding of a Pliocene cave, as that one had never before been discovered. From the evidence given by the Author, there was no room for doubting that these specimens had been obtained from the fissure, or pothole, although their mineral condition was so remarkably like that of the teeth found in the East Anglian Crags. The gnawed bones and preponderance of young animals made it highly probable that these remains were originally deposited in a 'hyæna-den' in Pliocene times; but it seemed also probable that they had been subsequently disturbed and redeposited, perhaps much more recently.

Although he preferred to regard the 'Forest-Bed' of Norfolk as the latest phase of the Pliocene, he did not think the question of its classification with the Pliocene or with the Pleistocene of primary importance; for all geologists were agreed as to its intermediate position.

Mr. Clement Reid congratulated the Author, and concurred with him as to the Pliocene age of the remains from Doveholes. They suggested a period probably of the date of the Norwich or Red Crag. The general question of the classification of the Pliocene and Pleistocene deposits, brought up by the Author, did not seem to arise from this discovery, for no one would refer the mammalia exhibited to the period of the Forest-Bed. He thought that several zones were represented in our Pleistocene. Whether the Cromer Forest-Bed should be classed as Pliocene or Pleistocene was a question of convenience, and of the balance of evidence yielded by its entire fauna and flora. If the Forest-Bed were transferred to the Pleistocene, the difficulties would not be overcome, but made worse; for its marine mollusca were almost identical with those of the Norwich Crag, while the rest of its fauna and flora seemed more to ally it with the strata below than with those above.

Dr. C. W. Andrews said that, with regard to the determination of the mammalia, he entirely agreed with the Author. The association of *Mastodon* with the other remains was of extreme interest, and the Pliocene age of the deposit was undoubted.

Dr. A. Smith Woodward said that the paper was an illustration of the importance of local observers, and laid stress on the admirable work done by Mr. Salt, of Buxton, who was the centre of all scientific information in the neighbourhood. There could be no possible hesitation as to the authenticity of the discovery. He had examined the specimens, and agreed that many showed marks of hyæna-teeth. The youthfulness of the *Mastodon*-teeth supported the Author's contention as to the cave-origin of the fauna. For various reasons, he held that the specimen of *Elephas meridionalis* was probably correctly determined.

The Author said that, with regard to a previous speaker's remark that he (the Author) had 'mixed up' the fauna of the Forest-Bed with that of the Lower Brickearth of the Thames Valley, it was only necessary to refer to the paper in question in the Quarterly Journal, in which the one is defined as the early and pre-Glacial, and the other as the Middle and probably Glacial. With regard to

Mr. Reid's method of classifying the Pliocene strata by the flora and mollusca, rather than by the mammalia, he remarked that it was inapplicable not only to the Pliocene, but to the whole of the Tertiary subdivisions. Prof. Gaudry proved, some 15 years ago, that the mammalia were 'en pleine évolution' in the whole of the Tertiary Era, while the rest of the animal kingdom had already assumed those forms which they present in existing nature. In other words, the mammalia alone had changed fast enough in the Tertiary age to be of use in marking the time on the geological clock. With regard to the vegetable kingdom, all geologists knew that the flora had changed far more slowly than the fauna, and was therefore less useful for classificatory purposes. The confusion imported into geological classification by ignoring this fact was illustrated by Heer's attribution of the flora of the North-American Cretaceous Beds to the Miocene, because of its practical identity with the Miocene flora of Switzerland. It took many years for this mistake to be rectified by the discovery of the Cretaceous reptiles by Marsh and Cope. The Author therefore attached no classificatory significance to the few fragmentary plants referred to by Mr. Reid. Nor did he feel inclined to agree with Mr. Reid as to the specific importance of the minute differences in the mollusca. He had tested the value of Prof. Gaudry's appeal to the mammalia in the classification of the Tertiary deposits, and found that it held good not only in Europe, but in North and South America, and in Australia. The principles laid down in his essay on the classification of the Tertiary Era by means of the mammalia, published in the Quarterly Journal, were applicable to the rest of the world.

13. *The* AMOUNTS *of* NITROGEN *and* ORGANIC CARBON *in some* CLAYS *and* MARLS. By Dr. N. H. J. MILLER, F.C.S. (Communicated by Sir JOHN EVANS, K.C.B., D.C.L., F.R.S., For.Sec.G.S. Read February 25th, 1903.)

BEFORE discussing the results obtained from the different deposits which form the subject of this note, it will be useful to consider some of the changes which we know the organic matter of soils is liable to undergo. The nature of these changes will depend mainly on the conditions of aëration, on the climate, and on the character of the mineral substances with which the vegetable matter is associated; and the chemical properties of the predominating constituents of the decaying plants, which may be proteids, carbohydrates, or resins, etc., may, according to circumstances, have an important influence on the character of the products.

Without going into the complicated questions involved in the breaking-down of the different plant-constituents, or the question of the production of complex organic substances from elementary nitrogen, it may be stated that the general, but not invariable, tendency of decaying vegetable matter is to become more nitrogenous, owing to the relatively greater ease with which, under most conditions, gaseous compounds of carbon are liberated as compared with nitrogen. An example of a change of this kind is afforded by some analyses made in 1865, 1881, and 1893, of the soil of the continuously unmanured plot of the Rothamsted wheat-field. The results (see Table I, below) show a decrease in the amount both of total nitrogen and of organic carbon, the loss of carbon being relatively greater than that of nitrogen.

TABLE I.—CARBON AND NITROGEN IN THE ROTHAMSTED WHEAT-SOIL.
(Broadbalk Field. First 9 inches. Plot 3.)

	Organic Carbon.	*Total Nitrogen.*	*Carbon to 1 of Nitrogen.*	*Nitrogen to 100 of Carbon.*
	Per cent.	Per cent.		
1865	(1·100)	0·1090	10·1	9·9
1881	0·977	0·1009	9·7	10·3
1893	0·888	0·0940	9·4	10·6

In this old, arable soil, which has had no manure at all since 1843, the loss of nitrogen is now hardly appreciable, while the loss of carbon, although slight, is much more marked. Where there has been a recent application of organic manure, the losses will naturally

be far greater; but, as time goes on, the organic matter, which in recently dunged soil contains a relatively high percentage of carbon, will gradually become more and more nitrogenous. Evidence on this point is furnished by some of the results obtained in 1882, from the soil of the barley-field at Rothamsted. The plots include among others one (7^2) permanently dunged, one (7^1) which had 14 tons of farmyard manure for the twenty years ending in 1871, but none since, and an unmanured plot (O 1). The percentage amounts of organic carbon and of total nitrogen in the soil dried at 100° are stated in the following table:—

TABLE II.—CARBON AND NITROGEN IN HOOSFIELD BARLEY-SOIL.

(First 9 inches.)

Plot.		*Organic Carbon.*	*Total Nitrogen.*	*Carbon to 1 of Nitrogen.*	*Nitrogen to 100 of Carbon.*
		Per cent.	Per cent.		
7^2	14 tons of farmyard manure...	2·486	0·2131	11·7	8·6
7^1	14 tons of farmyard manure. Unmanured since 1871.	2·032	0·1798	11·3	8·9
O 1	Unmanured since 1851	1·021	0·0930	11·0	9·1

It is evident that, while the soil of plot 7^1 has lost a certain amount of nitrogen since the application of farmyard manure was discontinued, the loss of carbon has been still greater; and it is to be expected that some years hence the relations of nitrogen and carbon in this plot will be quite similar to those of the plot O 1, which has been without organic manure since the commencement of the experiments. In a lighter and warmer soil, the reversion to its original state would be more rapid. At Grignon, for instance, Dehérain [1] found that the percentage of carbon in a soil left unmanured was reduced to about half in ten years, but this result must be regarded as quite exceptional. When an application of dung is discontinued, the rate of decomposition will naturally become slower; and if it happens that non-nitrogenous substances of a relatively stable character are present, the loss of nitrogen may eventually exceed the loss of carbon.

As regards the effects of extreme conditions of climate, Hilgard [2] has investigated the soluble humus in the soils of dry and wet regions in California. He found that, while the total amount

[1] Ann. Agronom. vol. xv (1889) p. 481.
[2] Ann. Rep. Agric. Exper. Stat. Univ. Californ. 1894, p. 66.

of soluble nitrogen did not vary much in the two classes of soils, the amounts of soluble humus,[1] and consequently the percentage of nitrogen in the humus, varied considerably.

Table III.—Soluble Humus and Soluble Nitrogen in Arid and Humid Soils in California.

	Soluble humus.	*Nitrogen in soluble humus.*	*Soluble Nitrogen in soil.*
	Per cent.	Per cent.	Per cent.
Arid soils: uplands, California......	0·75	15·87	0·101
Arid soils: lowlands, California ...	0·99	10·03	0·102
Humid soils	3·04	5·24	0·132

The total nitrogen and the organic carbon in the soils were not determined, but the results tabulated above afford clear evidence of the essential difference in the character of the humus produced under the different climatic conditions. Hilgard also showed, in accordance with the observations of Armsby, Wollny, and others, that accumulation of nitrogen is promoted by the presence of earthy carbonates, and that ferric hydroxide acts in the opposite direction.

Reference has already been made to the decreasing rate of the decomposition of organic residues, as a necessary consequence of the disappearance of their less stable constituents. It is probable that almost the whole of the organic matter[2] which remains near the surface will, sooner or later, be resolved into substances which living vegetation is able to assimilate. It must, however, be borne in mind that nearly all soils contain, in addition to the residues of their present and past vegetation, more or less organic matter belonging to the original deposit, and that this organic matter has, in many cases, according to the geological formation to which it belongs, undergone further changes which render the production, or re-production, of anything of the nature of humus impossible.

It is evident therefore, that if, as is undoubtedly the case, it is useful to make a distinction between the soluble, or more immediately available, and the insoluble humus, it is equally essential

[1] Soluble humus (Grandeau's matière noire) is the substance dissolved from soils by weak alkali-solutions, after removal of the bases by extracting the soil with dilute hydrochloric acid. The term 'soluble nitrogen' refers to the organic nitrogen present in the soluble humus obtained in the manner described.

[2] Except, of course, certain animal remains, especially the hard chitinous portions of insects which are extremely resistant, and which, as pointed out by P. E. Müller ('Die Natürlichen Humusformen' Berlin, 1887) may sometimes occur in considerable quantity.

to know, at any rate approximately, how much of the total organic matter in our soils is humous and how much bituminous—in other words, to what extent, if at all, the organic matter of the original deposit is an immediate product of the usual processes of decay of vegetable matter, or whether it has undergone the more drastic treatment under which coal and allied substances have been produced. A good deal may be learned by a study of the subsoils, as even a few feet below the surface comparatively little of the organic matter can be due to recent vegetation; but a systematic examination of deeper deposits is very desirable in this connection.

The large areas of peat-land known as 'Hochmoor' contain relatively little nitrogen near the surface, but much more a few feet below. Detmer [1] tabulates the following analyses (calculated as percentages in the substances free from ash) of peat from Jessbeck in Schleswig-Holstein:—

TABLE IV.—COMPOSITION OF PEAT AT DIFFERENT DEPTHS.

	Organic Carbon.	*Total Nitrogen.*	*Hydrogen.*	*Oxygen.*	*Carbon to 1 of Nitrogen.*	*Nitrogen to 100 of Carbon.*
	Per cent.	Per cent.	Per cent.	Per cent.		
Surface	57·75	0·80	5·43	36·02	72·2	1·4
7 feet deep ...	62·02	2·10	5·21	30·67	29·5	3·4
14 feet deep ...	64·07	4·05	5·01	26·87	15·8	6·3

We possess, of course, no evidence that the vegetation from which the lower layers of the peat are derived was identical in composition with that of later growth. But the high percentage of nitrogen at a depth of 14 feet must be mainly due to losses of oxygen in combination with carbon, as well as to losses of hydrogen, probably as marsh-gas. The original peat contained 2·72, 7·42, and 9·16 per cent. of mineral matter respectively at the different depths.

A more detailed examination of the non-nitrogenous matter of peat was made by Dr. Hjalmar von Feilitzen,[2] and his results confirm those of Detmer, as regards the gradual increase in the proportion of carbon concurrently with the increase in depth, notwithstanding that the peat rapidly loses two prominent non-nitrogenous constituents—cellulose and furfuroids. The peats investigated by H. von Feilitzen were of the 'Hochmoor' variety, derived from vegetation which thrives when the surrounding water is deficient in lime and other mineral plant-food. Absence of lime has been

[1] Landw. Versuchs-Stationen, vol. xiv (1871) p. 271.
[2] Journ. Landw. vol. xlvi (1889); see also Hj. von Feilitzen & B. Tollens, Ber. Deutsch. Chem. Gesellsch. vol. xxx (1897) p. 2571.

shown by Hilgard to be favourable to the accumulation of carbon.

As already hinted, the study of ordinary soils and subsoils is complicated by the presence of organic residues of two widely separated periods. A few feet below the surface the organic matter must, however, be mainly that which was deposited along with the soil. In the following table are some average results which were obtained with soil-samples from nine of the Rothamsted grass-plots (which have been under grass for at least 300 years, and probably much longer), and also the averages obtained with all the plots of the wheat-field (excluding the surface-soil of the two dunged plots).

TABLE V.—ORGANIC CARBON AND TOTAL NITROGEN IN ROTHAMSTED SOILS.

Depths of 9 inches.	*Carbon.*		*Nitrogen.*		*Carbon to nitrogen.*		*Nitrogen to 100 carbon.*	
	Park-soil. 1876.	*Wheat-soil.* 1893.	*Park-soil.* 1876.	*Wheat-soil.* 1893.	*Park-soil.* 1876.	*Wheat-soil.* 1893.	*Park-soil.* 1876.	*Wheat-soil.* 1893.
	Per cent.	Per cent.	Per cent.	Per cent.				
1st ...	3·292	1·076	0·247	0·1149	13·3	9·4	7·5	10·7
2nd...	0·845	0·640	0·081	0·0784	10·4	8·2	9·6	12·2
3rd ...	0·432	0·492	0·050	0·0666	8·6	7·4	11·6	13·5
4th ...	0·310	0·339	0·043	0·0511	7·2	6·6	13·9	15·1
5th ...	0·251	0·279	0·040	0·0472	6·3	5·9	15·9	16·9
6th ...	0·215	0·256	0·036	0·0430	6·0	5·9	16·7	16·8
7th ...	...	0·248	...	0·0420	...	5·9	...	16·9
8th ...	...	0·215	...	0·0396	...	5·4	...	18·4
9th ...	...	0·189	...	0·0391	...	4·8	...	20·7
10th ...	...	0·188	...	0·0375	...	5·0	...	19·9

It is of interest to note, that while the surface-soil of the grass-plots contains much more organic matter than that of the wheat-field, the subsoil contains rather less. The composition of the organic matter of the subsoil, as indicated by the relation of nitrogen to carbon, is almost the same in the two fields. In view of the comparatively slight changes in the amount of total nitrogen below 4 feet, the diminution in the percentage of carbon is greater than would be expected; it may, to some extent, be due to recent root-residues, which would diminish in quantity with the distance from the surface. It seems safe to conclude that the original organic matter of these soils had a high relation of nitrogen to carbon, and that the conditions under which the soils were formed were favourable to the elimination of carbon.

An example of a soil may now be given, in which carbon was retained in unusually large amounts. The soil, which was obtained in 1882, was unbroken prairie-land near Selkirk (Manitoba). Both the organic carbon and the total nitrogen in the surface-soil, which is nearly black, are very high; but the soluble nitrogen, although present in considerable quantity, is lower in relation to the total nitrogen than is the case in Rothamsted soils.

TABLE VI.—ORGANIC CARBON AND NITROGEN IN MANITOBA PRAIRIE-SOIL.

Depths of 12 inches.	*Organic carbon.*	*Total nitrogen.*	*Carbon to 1 of nitrogen.*	*Nitrogen. to 100 of carbon.*	*Soluble humus.*	*Nitrogen in soluble humus.*	*Soluble nitrogen in soil.*
	Per cent.	Per cent.			Per cent.	Per cent.	Per cent.
1st	7·58	0·618	12·3	8·2	5·93	4·08	0·2423
2nd	3·68	0·264	13·9	7·2	—	—	—
3rd	1·53	0·076	20·0	5·0	—	—	—
4th	1·09	0·042	26·0	3·9	—	—	—

The sudden fall in the percentage of nitrogen in the subsoil is very striking. At a depth of 4 feet the amount of nitrogen is very nearly the same as in the Rothamsted subsoil. The percentage of carbon is, however, unusually high, and the organic matter as a whole very different in composition from that present in our clay-subsoil.

Composition of the Deep Clays and Marls.

The samples of the various deposits were obtained, through the kindness of Sir Archibald Geikie, from the Geological Survey. The following is a list arranged in chronological order :—

1. Lower Lias. Mickleton Boring (Gloucestershire).
2. Oxford Clay. Brabourne Boring, at 1370 feet.
3. Kimmeridge Shale. Subwealden Boring, Netherfield (Sussex).
4. Purbeck. Penshurst Boring, at 1074 feet.
5. Do. do. do. at 1015 feet.
6. Wealden. Brady Shaft, Dover, 472–478 feet.
7. Do. Mottled clay. Brabourne Boring, at 591–611 feet.
8. Gault. Meux's Brewery, Tottenham Court Road.
9. Chalk Marl. Meux's Brewery.
10. London Clay, from Electric Railway-Tunnel, Piccadilly Circus.

In addition to the above, reference will be made to a sample of Oxford Clay, obtained in 1876 from the Subwealden Exploration Boring, at a depth of between 500 and 600 feet.

Apart from the interest due to the great depths at which the samples were obtained, and the evidence that they afford of enormous

accumulations of combined nitrogen, they possess further and greater value as representing the materials from which large areas of our soils are derived.

With regard to the amounts of nitrogen in the various deposits (see Table VII), the results show less variation than might be expected, the percentages being, in nine cases out of eleven, between 0·032 and 0·053. The limits in the case of carbon are, however, much wider apart—0·299 to 1·299; and it is evident that the organic matter as a whole must vary greatly in its character. In every case the organic matter will include a variety of substances; and it is conceivable that the nitrogenous matter, in the London Clay for instance, may be very similar to that of the Rothamsted subsoil, the excess of carbon in the London Clay being due to the presence of some non-nitrogenous substances. The relatively high amount of nitrogen in the Kimmeridge Shale is somewhat unexpected, and may in part be connected with the presumably animal origin of the deposit. In contrast to this, we find in the Purbeck Clay (No. 5) more than 40 times as much carbon as nitrogen.

TABLE VII.—CARBON AND NITROGEN IN CLAYS AND MARLS.

	Calcium-carbonate.	*Organic carbon.*	*Total nitrogen.*	*Carbon to 1 of nitrogen.*	*Nitrogen to 100 of carbon.*
	Per cent.	Per cent.	Per cent.		
1. Lower Lias.........	15·8	0·847	0·051	16·6	6·0
2. Oxford Clay	21·4	0·786	0·053	14·8	6·7
3. Kimmeridge Shale	52·2	0·386	0·036	10·7	9·3
4. Purbeck	82·1	0·470	0·021	22·4	4·4
5. Do.	73·4	1·299	0·032	40·6	2·6
Subwealden.........	[Oxford	Clay]	0·044	—	—
6. Wealden............	5·8	1·229	0·069	17·8	5·6
7. Do.	—	0·534	0·033	16·0	6·2
8. Gault	30·6	0·613	0·036	17·0	5·8
9. Chalk-Marl	35·4	0·299	0·033	8·8	11·0
10. London Clay	7·2	0·391	0·041	9·5	10·5

Speculation as to the precise nature of these various forms of organic matter, and the causes of the variations in their composition, is, however, premature. The important question is whether, in the case of these older deposits, the organic matter which is evidently, sometimes at any rate, of a bituminous nature, contains any humus at all—the term humus including not only the substances soluble in weak alkali, but also the insoluble residues of decaying vegetable matter. The distinction is of considerable importance in agriculture,

since, without entirely accepting the opinion that insoluble humus possesses no manurial value, there is no doubt that the much more stable products—hydrocarbons, etc.—obtained from humus and from vegetable matter generally, under the combined influence of heat and steam, are quite useless to crops.

From this point of view, it seems very desirable that the organic matter present in the deposits which form the basis of many soils should receive far more attention than has hitherto been given to them; and the chief object in recording these results, few and incomplete as they are, is to call attention to a line of investigation which possesses both geological and economic interest.

Discussion.

The President referred to the results worked out by the Author as affording another illustration of the bearing of geological facts and phenomena upon agriculture. Few analyses of rock-formations from deep borings had yet been published, and it was desirable, both from the geological and the economic points of view, that such analyses should be multiplied, and compared with analyses of the same material when occurring at or near the surface, both before and after it had supported vegetation.

Prof. H. E. Armstrong said that he feared he could add little to the paper, which dealt with a very difficult and intricate question. He would like to know what the Author implied by his distinction between humous and bituminous constituents. Carbon and nitrogen, where present, must have an organic origin. Perhaps the Author intended to distinguish as between the presence of those elements in a form available for the nutrition of plants, and their presence in a form not thus available. Hitherto it had been the practice to look upon the subsoil as agriculturally of small importance, but the speaker suggested that it was desirable to make experiments in which the top soil would be got rid of altogether. We ought to be informed as to the amounts of potash and phosphoric acid: the organic constituents, as they stood, were of small value. The paper was a valuable beginning, but it did not carry one very far towards the solution of the problem which it attacked.

Mr. Whitaker considered that the Author deserved thanks for giving the results of his work, so far as they went, without waiting for several years till he had completed it. One or two specimens of London Clay were not a sufficient criterion, as its constitution differed widely in various localities, and the same would hold in other cases. He pointed out that the subsoil was made use of in former times, instancing the practice of 'marling' with Boulder-Clay and with Chalk. It should be borne in mind that the Author's results applied to clays from deep borings, where the influence of atmospheric agencies was unfelt.

Mr. Hudleston said that, as a 'distressed agriculturist' farming 600 acres of land, he was anxious to learn how the fertility of the soil might be increased, but he had not gathered much in that

regard, either from the paper or from the discussion. The amounts of carbon and nitrogen in the subsoil were, however, of considerable geological interest. He pointed out that the percentage of nitrogen was stated to be higher in the Kimmeridge Clay than in the Purbeck Clays; and, as a rule, Kimmeridge-Clay soils were fertile. As to the manurial values of subsoils, it was advisable to consult experience rather than theory. Most blue clays, when added to a soil, diminished its value; it was far better to add a red (or thoroughly oxidized) subsoil, and the best that he knew of was the red Permian 'marl' of Devon.

14. *The* GRANITE *and* GREISEN *of* CLIGGA HEAD (WESTERN CORNWALL). By JOHN BROOKE SCRIVENOR, Esq., M.A., F.G.S.[1] (Read February 4th, 1903.)

[Map on p. 144.]

THE small mass of granite known as Cligga Head, forming a bold promontory between St. Agnes and Perranporth on the northern coast of Western Cornwall, has long been known, not only to the geologists of that county, but also to others from farther afield.

Conybeare,[2] in 1817, from notes by Buckland, described a small formation at Cligga Point which would 'probably be considered by the Wernerian school as the newer granite,' and remarked on the stratification and the fact that it was worked for tin. A sketch also is given of the headland (*op. cit.* pl. xxiii), which does not, however, show the leading features exactly as they occur.

In 1818, Joseph Carne[3] spoke of granite at Cligga Head, apparently stratified obliquely, but proving, on a nearer view, to be traversed by small veins of 'blackish quartz, whose contemporaneous formation can scarcely be doubted.' In a footnote the same author wrote:—

> 'The granite at Cligga Point (if it is not a large elvan-course) might be called secondary or transition granite, without affecting the age of the granite of other parts of Cornwall, as it is far from the large granite-chain' (*op. cit.* pp. 74–75).

In 1820 Sedgwick[4] gave a description of the granite, as resembling the common granite of the country, except the 'intermediate parts,' which exhibited varied modes of aggregation: the strong folding of the parallel 'beds' in the granite was also noticed.

Œynhausen & Dechen,[5] in 1829, noted the 'numberless veins of granite which intersect the granite itself,' giving a stratified appearance to the rock.

Boase[6] in 1830, and Henwood in 1838[7] and 1843,[8] gave accounts of the mineral composition of the mass, the latter author emphasizing the 'jointed' structure and variation in composition.

Prof. C. Le Neve Foster[9] was, it is believed, the first to explain the true nature of the phenomena seen at Cligga Head. In 1877 he described and illustrated the alternation of granite and greisen, which produces the stratified appearance, attributed this formation of the greisen to vapours acting on the walls of fissures, and showed that the mass found a parallel, not only in the mode of occurrence of the greisen, but also in the curvature of the veins, in the tin-lodes of Zinnwald. Besides quartz and muscovite, tourmaline, gilbertite,

[1] Communicated by permission of the Director of H.M. Geological Survey.
[2] Trans. Geol. Soc. vol. iv (1817) p. 401 & pl. xxiii.
[3] Trans. Roy. Geol. Soc. Cornw. vol. ii (1822) p. 80.
[4] Cambr. Phil. Soc. Trans. vol. i (1822) p. 131.
[5] Phil. Mag. & Ann. vol. v (1829) p. 169.
[6] Trans. Roy. Geol. Soc. Cornw. vol. iv (1832) p. 303.
[7] Twentieth Ann. Rep. Roy. Inst. Cornw. (1838) p. 29.
[8] Trans. Roy. Geol. Soc. Cornw. vol. v (1843) p. 93.
[9] *Ibid.* vol. ix (1878) p. 213.

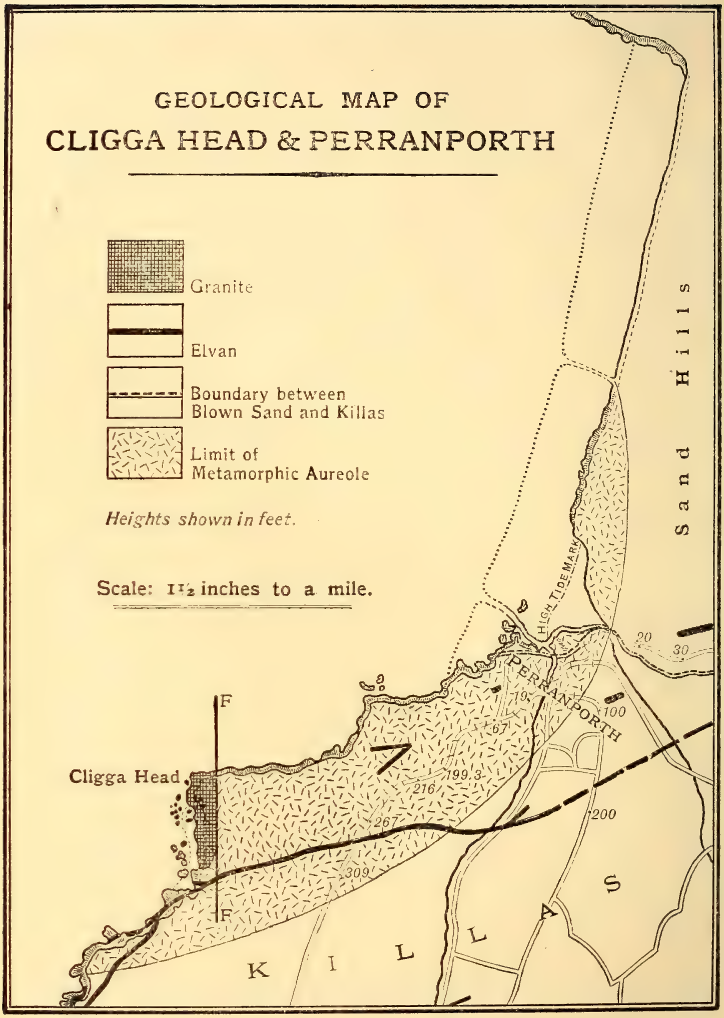
and a little cassiterite are mentioned as occurring in the greisen; cassiterite, wolfram, lithomarge, lepidolite, and mispickel as being found in the quartz-veins traversing the centres of these greisen-bands. Concerning this description of Cligga Head, we can only wish that Prof. Le Neve Foster had had more time to devote to what he very justly described as one of the most magnificent sections in Cornwall; for, although brief, his paper contains a very graphic account of the principal characteristics of the section of the granite which faces westward.

During the summer of 1902 I was engaged in re-mapping the country round Perranporth and St. Agnes, and found that there was still much to be said concerning the Cligga-Head granite, which affords an ideal opportunity of studying metasomatic alteration in a tin-bearing district. Although formerly easy of access, the Cligga section is now on the grounds of Nobel's Explosive Factory, established on the promontory a few years ago. But, thanks to the courtesy of the manager, Mr. Joseph Turner, I was enabled to make several visits to the headland; and I am anxious here to record my indebtedness both to him and to his son, Capt. Turner, for their unfailing efforts on my behalf, in giving me every assistance in their power. To Capt. Turner I owe an especial debt of gratitude for his help, which considerably lightened my task, in examining the granite-section.

It is necessary first to give a brief sketch of the geology of this part of Cornwall. The 'country' is killas, composed chiefly of bands of felspathic mudstones with grey shale-partings, striking roughly east and west, and disturbed by innumerable dislocations. Two elvan-courses, which can be traced for some miles, cut this strike obliquely, trending 20° north of east: one the St. Agnes elvan, a typical quartz-porphyry; the other, the granitic elvan of Perranporth. Nearer the Cligga granite are several outcrops of smaller elvans similar to the St. Agnes elvan. The nearest large mass of granite is that of Redruth and St. Day, 9 miles distant; while the St. Austell mass is 14 miles away to the east. There is, however, a small granite-outcrop much nearer, that of St. Agnes, only 4 miles distant: this patch of granite, although very badly exposed, presents interesting points of similarity to the Cligga mass, as will be shown later. That the Cligga-Head granite was intruded into the killas like the other, and larger, granite-masses of Cornwall, there can be no question; for the metamorphism, which results in a brown tourmaline-rock at the junction,[1] and in bleaching and spotting of the shales and mudstones for some distance beyond, is strongly marked. Although this spotting is generally a most unsatisfactory guide when attempting to map an aureole of metamorphism in Cornwall, it was found possible in this case to draw a satisfactory boundary;

[1] Prof. Le Neve Foster, in Trans. Roy. Geol. Soc. Cornw. vol. ix (1878) p. 218, records molybdenite from the altered killas at the junction, but no one has been fortunate enough to find it again.

Fig. 1.



GEOLOGICAL MAP OF
CLIGGA HEAD & PERRANPORTH
Granite
Elvan
Boundary between
Blown Sand and Killas
Limit of
Metamorphic Aureole
Heights shown in feet.
Scale: 1½ inches to a mile.
Sand Hills
HIGH TIDE MARK
PERRANPORTH
Cligga Head
F
F
20
30
19
100
67
199.3
216
267
200
309
KILLAS

for, even should the spotting be found to be existent outside the aureole mapped in fig. 1 (p. 144), the bleaching alone, which can be traced in all its gradations to Pen-a-gader on the south-west and Chapel Rock on the north-east, allows of an aureole of the same form (which is the essential point in dealing with the Cligga granite) if not of the same extent.

To return to the granite: the form of the outcrop is elongated, the axis trending due north and south, and the section shows innumerable divisional planes trending about 20° north of east. In the sea, west of the cliff-section, are a number of skerries, chiefly of granite, but those opposite the southern end of the granite are of altered killas. Now, it will be seen by referring to the map (fig. 1), that from the junction with the killas on the south the granite-outcrop must have trended seaward to the north-west. Again, if the form of the divisional planes at the extreme south is examined, it will be found that the granite rests upon a steep wall of killas. This also is the case close by on the east; but there is this difference: the junction on the south is a plane-surface, while that on the east forms a shallow cup with the concavity pointing to the west. The only means of tracing the eastern junction northward is by old mine-débris on the Factory grounds, which just suffices to show that its direction is roughly parallel to the cliff-section. Nor can any better evidence be obtained from the slopes of the cliff facing northward, though it is possible to see the junction in the lower part of the cliff from a boat. It proves to be vertical, and is clearly defined, owing to the sea having driven a narrow chasm some feet into the face of the cliff along the plane of contact. The fact of this junction being vertical lends colour to the miners' supposition, quoted by De la Beche,[1] that the granite has the habit of a dyke. But my friend, Capt. Turner, placed at my disposal a mining report dated 1857 & 1858, discussing the advisability of re-opening the Perran United Copper Sett, formerly worked on the ground now occupied by the Explosives Factory, in which it is stated by Capt. John R. Pill that, apart from the exposure of the Cligga-Head granite, the main body of the granite comes near the surface at a point at sea-level three-quarters of a mile to the east, a fact unknown in De la Beche's time, and one that throws an entirely new light on the situation. In the first place it immediately explains the significance of the peculiar form of the metamorphic aureole, in relation both to the position and to the size of the visible outcrop; and in the second place, judging from this evidence, there seems to be no reason to doubt that this is a faulted junction, the downthrow of the fault being to the east. Yet that this fault, which agrees roughly in direction with the great 'cross-courses,' does not affect the whole of the eastern outcrop is evident from a study of the divisional planes at the extreme south of the granite-mass. It will be objected to this view by anyone who has seen Conybeare's figure[2] that this fault must necessarily break the course

[1] 'Geol. Rep. on Cornwall, Devon, & W. Somerset' 1839, p. 162.
[2] Trans. Geol. Soc. vol. iv (1817) pl. xxiii.

of the St. Agnes elvan, which, as a matter of fact, continues on its course apparently unbroken. Now, at St. Agnes, the elvan is dipping northward at an angle which becomes steeper at Wheal Prudence, and at Hanover Cove is within a few degrees of the vertical; not, as figured by Conybeare, remaining the same as at St. Agnes. The elvan is again exposed in the new railway-cutting in Perran Coombe, where it is seen to be dipping southward at an angle of 30°; therefore, at a point not far east of Hanover Cove, that is, at a point where the north - and - south fault probably cuts it, it must be vertical. Again, since the surface of the main body of the granite mentioned by Capt. Pill must be at least 300 feet below the top of the Cligga exposure from which it is severed, as can be seen from the contours, it is improbable that any appreciable horizontal motion has complicated the dislocation. Consequently, although the elvan may have been as fully affected by the fault as the granite, it need not necessarily have been thrown out of its course.

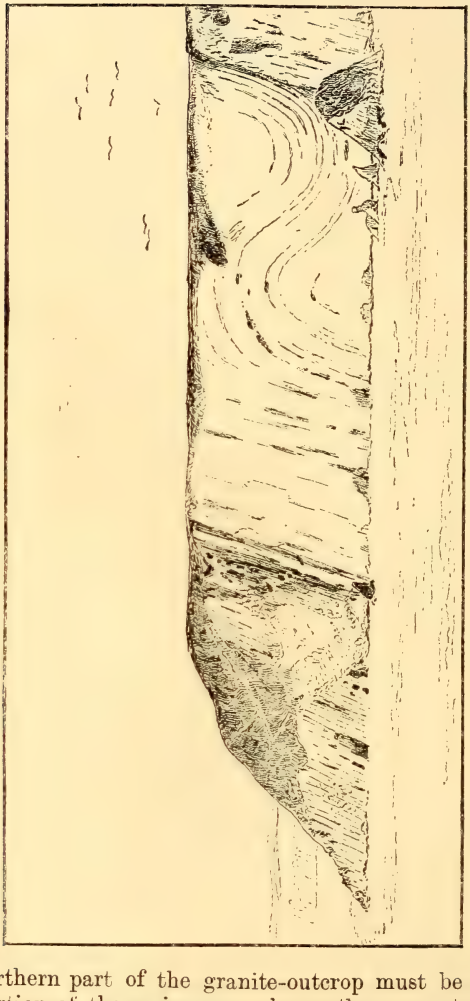


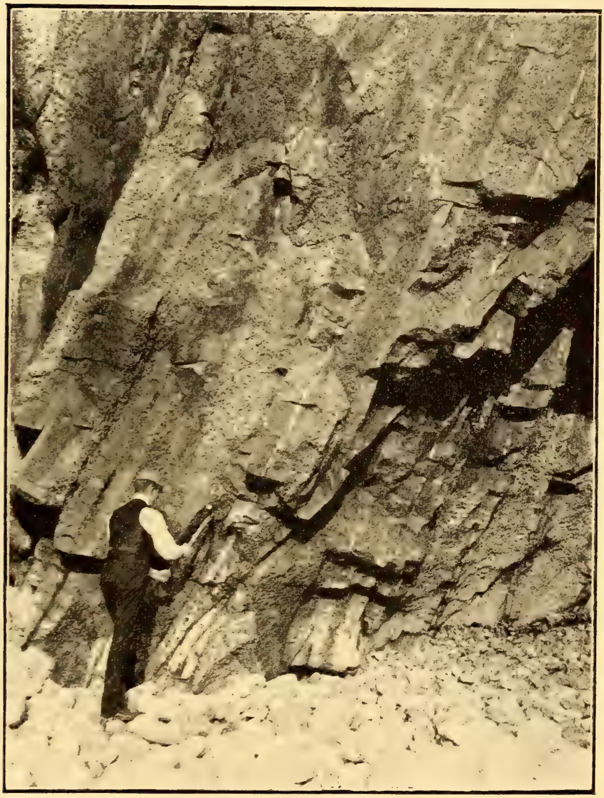
Fig. 2.—*View of Cligga Head.*

From this it follows that the northern part of the granite-outcrop must be taken as an isolated portion of the main mass, the southern as a tongue protruding out from it into the killas; and, moreover, it is possible, by observing the form of the divisional planes, to see where this tongue commences.

For a little more than halfway from the northern extremity of the section, these divisional planes are straight, and dip northward at an angle of about 60°. They then turn over and form an anti-

cline, after which they are bent again into a syncline, the southern limb of which rests against the abrupt wall of schorlaceous killas. The syncline is very clear; but the anticline would be difficult to make out, were it not for old mine-workings driven along the divisional planes. It is apparent from the actual exposure that the syncline is formed by the granite being 'bedded' parallel to the surface of killas into which it was intruded; and that this is the case also with the anticline there is no reason to doubt.

Fig. 3.—*Greisen-bands in the cliff at Cligga Head.*



The commencement of the anticline may then be considered the base of the granite-tongue, in which the divisional planes are, strictly speaking, 'bedding-planes' formed parallel to the surface of the 'country' during the process of cooling. North of the anticline the granite may be spoken of as 'the main mass,' where the divisional planes may also be safely spoken of as 'bedding.'

Besides the 'bedding-planes,' trending 20° north of east, a badly-defined series of joints can be seen in a hollow, in the main mass of

the granite, caused by the falling of the cliff. These have a north-and-south course; and in addition to them are three comby quartz-veins, two with a similar course to that of the joints, the third trending east and west. These quartz-veins mark fissures opened in the granite, subsequently to the formation of the 'bedded' structure, and need not be considered further.

The 'bedding-planes' are marked by bands of a dark-looking rock, already identified as greisen by Prof. Le Neve Foster. They vary in thickness from an inch, or even less in the tongue, to 20 inches. The granite-bands, owing to the number of the 'bedding-planes,' rarely exceed 20 inches in thickness, and that only in the main mass—very often they are less than 3 inches thick. Every greisen-band is traversed by a quartz-vein which occupies the fissure, along which the agents whereby the metasomatism of the granite was effected were conducted. The quartz-veins yield cassiterite in well-formed crystals, blue tourmaline, wolfram, mispickel, and, as may be inferred from the presence of decomposition-products, copper-pyrites. Prof. Le Neve Foster also mentions lithomarge and lepidolite.

In the granite-tongue the greisen-bands become very frequent and thinner: indeed, at the extremity, they appear to die out altogether in some cases; yet the 'bedding-planes' even then remain well defined, and contain minerals which will be described later.

A few east-and-west faults, with a small downthrow, can be seen cutting the greisen-bands as one proceeds along the beach; they are, however, of small importance, and may be dismissed without further notice.

Owing to the proximity of the 'bedding-planes,' one to another, the granite is nowhere in the Cligga section sufficiently fresh to warrant the preparation of slices for the study of the nature of the original minerals. It may be seen from a hand-specimen that the biotite is considerably bleached, exhibiting a bronzed appearance. In one specimen collected, the orthoclase, which is white, and sometimes forms porphyritic crystals an inch long, does not show much evidence of decomposition; but where the section is exposed to the mechanical action of the sea, the felspar has been, as a rule, completely removed. In addition to the white orthoclase, there is another, and not so abundant, felspar, which, when present, appears to form a zone on the extreme edges of the granite-bands, in place of the white felspar. In colour it is pink, with a tinge of orange which becomes more pronounced as decomposition advances. Porphyritic crystals of this felspar were not seen.

When traced into the greisen the felspars gradually disappear. Close to the granite, and, in the case of the porphyritic crystals, nearer the quartz-veins, their form can still be distinguished in the mass of quartz and mica; but more generally they are completely lost. A few of the biotite-crystals can also be seen in the greisen, but they are here even paler than in the granite.

The original quartz-grains, which, both in the granite and in the

greisen, show obscure traces of crystalline outline, remain apparently intact in the altered rock, and can be easily distinguished with the naked eye.

Numerous minute, dark, crystals of tourmaline occur throughout the granite and the greisen.

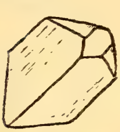
In order to study the transition from granite to greisen, as well as the weathered state of the former admits, slices were prepared from a series of specimens taken from the hollow mentioned on p. 147, starting from the granite and continuing to the quartz-vein in the centre of the greisen-band. The microscopic characters of the component minerals will first be described as briefly as possible.

The felspar in the granite, where distinguishable, is completely kaolinized; but the cleavage, as so often happens in decayed felspar, remains very distinct. For the most part, it has been replaced by minute flakes of muscovite with ragged outlines, and by secondary quartz, which occasionally shows an indistinct hexagonal form. In the greisen a trace of kaolinized felspar may be seen near the granite, though otherwise it is completely altered to secondary quartz and muscovite.

But for the absorption, the biotite, of which there is very little in the greisen, would be completely colourless; as it is, it shows a faint vandyke-brown, which is more pronounced in flakes parallel to the basal plane. The pleochroic halos, surrounding zircons and other, but undeterminable, inclusions are as perfect as those in fresh biotite, and by reason of the bleaching much more distinct. Magnetite occurs as a decomposition-product; and one biotite-crystal shows the commencement of a sagenite-web. A grain of brown tourmaline is sometimes included. Another, yellow, flaky, and presumably decomposition-product was observed in one grain. The axial figure is characteristic.

The original quartz, both in the greisen and the granite, forms large grains with few, but well-developed, fluid-cavities. On the periphery of almost every grain, however, the fluid-inclusions are much more numerous and slightly smaller than those in the centre. One or two minute zircons and one tourmaline-crystal are seen embedded in the clearer quartz, but near the quartz-vein, where it becomes somewhat difficult to distinguish between the original and secondary quartz. But the most remarkable inclusions are numerous long prisms with terminal faces, sometimes lying with no particular arrangement, though often orientated to the prism and pyramid-planes. By their form and colour, which is faint blue, they can only be referred to tourmaline. The average length of these inclusions is 0·16 millimetre; but one stouter prism, the form of which instantly suggests tourmaline (fig. 4), measures only 0·032 millimetre. That these prisms are actually embedded in the original quartz admits of no doubt.

Fig. 4.—*Prism of tourmaline included in quartz.*



[× about 800 diameters.]

The secondary quartz, derived from the felspar chiefly, but also in part from the biotite, forms much smaller grains than the original quartz, and contains many more, though slightly smaller, fluid-cavities.

In addition to the secondary quartz, there is another mineral apparently derived from the orthoclase. This is topaz, which occurs in minute grains, showing characteristic refraction and double refraction, but very rarely the cleavage parallel to 001 or the crystal-outline. In order better to determine this mineral, some of the rock was crushed, and separated in cadmium-borotungstate of sp. gr. 3·2. The grains afforded by this means showed the cleavage much better, and in one or two cases the prism-faces; moreover, one grain was found which gave an undoubted orthorhombic axial figure with the characteristic axial angle of topaz. Prof. Zirkel[1] mentions a complete replacement of felspar by topaz-grains, often retaining the outline of the original felspar; but, in these slides, the grains, although sometimes forming a considerable continuous mass, do not give any indication of the felspar-faces. Topaz was also found in the vein-quartz, and a few grains in the granite.

The tourmaline occurs as light-brown prisms with an uneven outline. The absorption is not so strong as is usual in tourmaline, except in some grains which show traces of a fine cleavage at right angles to the well-marked cross-fracture. The terminal faces are rarely indicated, the prisms generally fraying out instead into light-blue acicular bodies, the colour of which matches that of the inclusions in the original quartz, when of similar dimensions. One very peculiar feature is presented by these light-brown tourmalines: there are numerous zircons enclosed in them, with pleochroic halos identical with those in the biotite; and one grain also has included the yellow flaky substance mentioned in connection with that mica before. Moreover, a few quartz-grains may be seen in the tourmaline.

In the vein-quartz there are stout prisms of tourmaline; but these are always blue.

Cassiterite occurs in the greisen sparsely; the crushed rock afforded a few grains showing the irregular colouring, the cleavage parallel to 100, and, more rarely, a trace of the prism-faces.

In addition to the muscovite derived from the orthoclase, another mica forms small nests in the greisen: in section it cannot be distinguished from muscovite; but in a hand-specimen it resembles gilbertite, a species created by Thomas Thomson[2] in 1836.

The principal minerals produced in the greisen-area are then: secondary quartz, muscovite, topaz, and brown tourmaline; and it may be safely stated that, in this case at any rate, the first three—quartz, muscovite, and topaz,—have been derived from the orthoclase.

From analyses given by Dana it is calculated that in the change from orthoclase to muscovite and topaz, roughly 49 per cent. of

[1] 'Lehrb. d. Petrographie' 2nd ed. vol. ii (1894) p. 123.

[2] 'Outlines of Mineralogy, Geology, & Mineral Analysis' vol. i, p. 235.

silica is set free. The abundance of the quartz in greisen as compared with that in granite is well known; and its secondary formation has also been noted in other granite-masses. For instance, Prof. Bonney, in describing trowlesworthite,[1] calculates that in the change from felspar to tourmaline, 43·9 per cent. of silica would be liberated; and in his paper on luxullianite the same author accounted for the abundance of quartz by a similar process. We may, therefore, conclude that the peculiar quartzose appearance of greisen is due to the formation of secondary silica, consequent on the breaking down chiefly of the orthoclase, but also of the biotite, the amount derived from the latter being in fact roughly 17 per cent., as will be shown later.

In discussing the origin of the brown tourmaline in luxullianite, Prof. Bonney suggested that that mineral may have been derived from the biotite of the granite: in his description of trowlesworthite,[2] this derivation is stated as an indubitable fact. In the Cligga-Head greisen there can be also no doubt whatever that the bulk, at any rate, of the tourmaline has been derived from the biotite. The presence of zircons alone suggests this; the fact that the pleochroic halos are preserved strengthens this suspicion; and the argument is clinched by the presence of 'transition-grains,' one of which not only shows the basal fracture of tourmaline, but the basal cleavage of the biotite at right angles to the tourmaline-fracture, numerous zircons and other inclusions with pleochroic halos,[3] and traces of the supposed yellow decomposition-product in the biotite. This grain also shows the more strongly-marked absorption mentioned above: indeed, we may argue that those grains which show stronger absorption than is generally seen in the tourmaline of this rock are grains in which the metamorphosis from biotite to brown tourmaline has not been completed.

The inference which I have drawn from the study of these slides is that all the brown tourmaline has been formed from the biotite; but as this conclusion might be questioned, it is well to offer the following considerations in its support.

Prof. Bonney suggested that the blue tourmaline in luxullianite had been derived from the orthoclase; indeed, this may be taken as an established fact. Again, apart from granite-modifications, it was noted lately, while examining some slides prepared from the St. Agnes tin-lodes, that it may be laid down as a general rule that the tourmaline formed in the walls of the lode (capel)—that is to say, in the shales and mudstones of the killas—is brown, while that enclosed in the quartz of the lode is blue,[4] an arrangement which is paralleled in the quartz-veins and greisen of Cligga Head. Now,

[1] Trans. Roy. Geol. Soc. Cornw. vol. x (1887) p. 182. [2] *Ibid.* p. 185.

[3] S. Allport, Quart. Journ. Geol. Soc. vol. xxxii (1876) p. 417, mentions 'dark spots' surrounding minute enclosures in a green alteration-product of tourmaline.

[4] Exceptions to this distribution of brown and blue tourmaline undoubtedly occur: for example, see Allport, *op. supra cit.* p. 415, & J. H. Collins, Min. Mag. vol. iv (1880) p. 20.

from the analyses quoted by Prof. S. L. Penfield and Mr. H. W. Foote,[1] brown tourmalines are shown to be essentially 'magnesia-tourmalines'; dark brown, 'magnesia-iron tourmalines'; and it will be seen from the analyses of Dr. R. Scharizer[2] that the percentage of alumina is slightly greater in blue than in brown tourmaline; the percentage of magnesia and lime much more in brown than in blue; the percentage of alkalies slightly greater in blue; and that there is no fluorine in the blue specimens quoted, while a very small but calculable quantity is present in some brown tourmalines; also that titanium is only quoted in one blue, while it is constant and reaches as much as 0·37 per cent. in the brown specimens.

The presence of the minute, pale-blue prisms in the original quartz of the Cligga granite proves that tourmaline was present in the magma as an original constituent: there is nothing very extraordinary in this, for Dr. Karl Dalmer[3] has shown that in the granites of Schellerhau and Altenberg topaz is found as a primary constituent; Dr. W. Salomon & Dr. H. His[4] have noted the same fact in the case of the greisen of Geyer; and Mr. J. J. H. Teall[5] writes that it must be admitted that in many cases the tourmaline plays the role of a normal constituent. Again, there is no evidence to show that the blue tourmaline in the lodes has been derived from any other mineral, and Prof. Bonney further noted the fact that in a schorl-rock at Mousehole[6] the blue tourmaline-prisms surrounding the more massive brown tourmaline-crystals are formed when felspar-crystals are contiguous to the spot occupied by the brown tourmaline. It may, therefore, be taken as at least very probable that all wholly blue tourmaline in granite-modifications and lodes has either been derived from orthoclase, or crystallized in its present state directly from the magma, whether fluid or vaporous.

In the Cligga granite there have been two main processes of decomposition—orthoclase affording muscovite, topaz, and quartz; biotite affording brown tourmaline, magnetite, and quartz: can any of the tourmaline have been derived from the felspar? In the case of orthoclase 49 per cent. of silica has separated out as quartz; in the case of biotite, as may be seen from a comparison of the silica- and alumina-percentages in biotite and tourmaline, roughly 17 per cent. only could have separated. If any tourmaline had been formed from the felspar, the amount of secondary silica in the greisen would be approximately the same; so that no comparison between the silica-percentage in the granite, even were it fresh enough, and that in the greisen would help in deciding the question. We know, however, that the most active reagent introduced into the granite has been fluorine, and that it was present in considerable quantities is evident from the abundance of topaz. Now, it has been proved

[1] Am. Journ. Sci. ser. 4, vol vii (1899) p. 97.
[2] Zeitschr. f. Krystallogr. vol. xv (1889) p. 337.
[3] Zeitschr. f. Prakt. Geol. vol. ii (1894) p. 320.
[4] Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xl (1888) p. 570.
[5] 'Brit. Petrogr.' 1888, p. 315.
[6] Min. Mag. vol. i (1877) p. 219.

that, if a rock be powdered up and gradually dropped into a platinum-dish containing hydrofluoric acid, the glassy portions, if any glass be present, will be first attacked, then the felspar, then the quartz-grains, and lastly the ferromagnesian minerals.[1] From this we may infer that the fluorine, in whatever form it was introduced, would attack the orthoclase in the granite, and leave the biotite to be decomposed by the less active, but no less important, factor in the metasomatism of this granite, boracic acid. It is quite probable that a little of the fluorine attacked the biotite simultaneously with the boracic acid: Dr. Scharizer's analyses show this to be so. But that any of the boracic acid was able to attack the felspar in the face of the fluorine seems just as improbable.

It has been mentioned (p. 150) that the brown tourmaline is often frayed out into blue acicular tourmaline: this may be interpreted in one of two ways. Either minute traces of the original felspar contiguous to the biotite have been spared from the fluorine and incorporated in optical continuity with the brown tourmaline by the boracic acid, certainly an improbable contingency; or, and this seems a more reasonable view to take, the decomposition of the easily-cleavable biotite took place over the whole surface of the cleavage-plates simultaneously, and the magnesia and titanium-dioxide segregated in the central portions of the tourmaline-crystals. Whether those crystals of tourmaline which occur in other parts in connection with the West-country granites (tourmaline which in cross-section shows a band of blue and brown, or alternate bands of those colours) admit of a similar explanation, is a point to be investigated at some future date.

Despite, then, the impossibility of determining by the secondary silica-percentage in granite and greisen whether tourmaline has or has not been formed from the felspar, in addition to muscovite and topaz, yet in the light of the analyses given by Dr. Scharizer, we may safely conclude from the foregoing considerations that the tourmaline has all been formed from the biotite; and, moreover, we may add as a corollary, that in a granite-modification containing quartz, muscovite, and only brown tourmaline, we may successfully look for topaz.

It cannot be said, of course, that the brown tourmaline in the killas has been derived from biotite, but there is a reasonable suggestion in the connection that can be made. In the ordinary course of metamorphism—that is, in the absence of fluorine and boron at the margin of the granite—the product at the contact would have been almost certainly brown mica. Now, knowing that brown tourmaline can be derived from brown mica, we may explain the presence of the former mineral in the killas by supposing 'potential molecules' of biotite to have been formed, which were prevented from crystallizing by the interference of boracic acid; or, to put it more simply, the boracic acid acted on 'nascent' biotite.

[1] Rosenbusch [transl. Iddings] 'Microscop. Physiogr. of the Rock-forming Minerals' 1888, p. 108.

With regard to the occurrence of topaz in greisens, it was found to be contained also in the greisen of the St. Agnes granite-mass, and this greisen was found to be in other respects identical with the Cligga rock, except for the fact that the original quartz-grains have not yet been seen to contain the orientated prisms of tourmaline. Macroscopic crystals of topaz were recorded by Greg & Lettsom [1] in the killas of Wheal Kind (Wheal Friendly ?) and Wheal Trevaunance; and Mr. J. H. Collins [2] mentions them also in slate at the Seal Hole tin-mine. All these localities are near to the St. Agnes granite. Topaz similar to that of the Cligga and St. Agnes greisens occurs in the St. Michael's Mount greisen, in addition to the well-known macroscopic crystals in the 'bedding-planes.' Topaz in the Continental granite-modifications is well known, but not always of similar origin. For instance, the only topaz mentioned by Prof. W. Salomon & Dr. H. His [3] in the greisen of Geyer occurs in nests, and is believed by those authors to be the original topaz of the granite.

The topaz-rock at Meldon, near Okehampton, described by Mr. Teall,[4] differs from the greisens in the abundance of plagioclase, in the absence of biotite, and in the green colour of the tourmaline.

It will be remembered that in a hand-specimen the original quartz-grains showed a tendency to form a crystal-outline, and that in section the blebs were seen to be generally surrounded by a thin band of quartz, which resembled the secondary quartz derived from the felspar. From the examination of the slides, there seems to be no doubt that each individual grain has been built on to by some of the secondary silica derived from the felspar and biotite, that this quartz has been deposited in optical continuity with the original grains, and that it has also produced the appearance of those grains being bounded by poorly-developed crystal-faces. Secondary growths of quartz in optical continuity in detrital deposits are well known. Dr. H. C. Sorby noted them in 1880 [5]; the Rev. Dr. Irving [6] recorded such growths in the sands above the Budleigh-Salterton Pebble-Bed in 1892; and my friend, Mr. H. H. Thomas, informs me that he has seen similar detrital grains, which, by the addition of secondary quartz, have formed dihexahedra. But secondary growths in the parent-mass are not so well known. In the case of hornblende and augite, instances have been recorded by Mr. Van Hise [7]; and Prof. Judd [8] states that he found abundant evidence of the growth of quartz and felspar at the expense of a more or less vitreous matrix—long after

[1] 'Manual of Mineralogy of Gr. Brit. & Irel.' 1858, p. 221.
[2] 'Mineralogy of Cornwall & Devon' 1871, p. 101.
[3] Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xl (1888) p. 570.
[4] 'Brit. Petrogr.' 1888, p. 316.
[5] Quart. Journ. Geol. Soc. vol. xxxvi (1880) Proc. p. 62.
[6] *Ibid.* vol. xlviii (1892) p. 71.
[7] Am. Journ. Sci. ser. 3, vol. xxxiii (1887) p. 385.
[8] Quart. Journ. Geol. Soc. vol. xlv (1889) p. 178.

the solidification of the rock, however, in the Tertiary granophyres of the Western Isles of Scotland and the North of Ireland.[1]

The greisen of Cligga Head differs from that of St. Michael's Mount in the absence, so far as has yet been ascertained, of apatite, which would denote the presence of phosphoric acid among the metasomatizing reagents. Nevertherless, it is not unsafe to predict that apatite will be found at Cligga Head, for Prof. Le Neve Foster [2] has recorded that mineral from the lodes of Wheal Kitty, situated between the Cligga and St. Agnes granite-outcrops; and for the same reason it may also be fairly expected that fluorspar will be found.

When at St. Agnes, I was told by two inhabitants of considerable experience that garnet had been found at Cligga Head, and was shown a specimen from that locality. Although not fortunate enough to find any specimens *in situ*, I do not hesitate to accept this statement, and would mention in support of it that Mr. Whitman Cross [3] records sanidine and garnet with topaz in the lithophyses of rhyolites from Colorado.

It has already been stated that in the granite-tongue the greisen-bands become very thin and frequent, and at the extremity appear to die out altogether in some cases. More than this, other modifications make their appearance; for veins of orthoclase and of fresh porphyritic biotite-crystals, some half an inch across, diversify the structure of the rock. With regard to the biotite, it appeared to me that the extremity of the tongue was considerably richer in that mineral than the rest of the granite; but owing to the altered state of that mica farther north no conclusive evidence can be adduced. It is a notable fact, at any rate, that the fresh condition of the biotite here indicates that the metasomatizing reagents did not affect the granite at the extremity of the tongue to such an extent as that at its root or in the main mass.

It only remains now to describe the minerals that were found lining the 'bedding-planes' at the extremity of the tongue. The actual source from which they were collected was a large fallen block lying at the bottom of the path which leads up the cliff at that point. Besides wolfram, which is commonly met with in the 'bedding-planes' there, topaz, lithia-mica, and a pink felspar occur.

The topaz occurs in short prisms, rarely exceeding a quarter of an inch in length, colourless or very pale green, and in one case forming a continuous mass coating the face of the rock. The form of the crystals is simpler than that described by Greg & Lettsom, and by Mr. J. H. Collins, as commonly occurring in the Cornish topaz. A typical crystal was measured and found to be made up of the

[1] For further literature on this subject, see Prof. Judd's paper above quoted.
[2] Trans. Roy. Geol. Soc. Cornw. vol. ix (1878) p. 210.
[3] Am. Journ. Sci. ser. 3, vol. xxxi (1886) p. 432.

forms 120, 021, & 111. The vertical striation of the prisms and the cleavage parallel to 001 are well developed.

The mica is brown when viewed in its natural state, but when powdered it exhibits a trace of the peculiar colour characteristic of lepidolite. It never shows a distinct outline, and it was found impossible to obtain a percussion-figure. The spectroscope gives a strong reaction for lithium ; and the powdered mica is unaffected by prolonged treatment with hot hydrochloric acid. The axial angle is about 60° (2 E). Despite the colour of the crystals, which is more characteristic of zinnwaldite than lepidolite, the absence of a percussion-figure and the resistance to hydrochloric acid make it unsafe to refer the mineral definitely to the former mica. Indeed, since I have been informed by my friend, Mr. H. L. Bowman, that it is sometimes impossible to separate zinnwaldite from lepidolite, this mica must be described simply as a lithia-mica.

The felspar at first suggested microcline or orthoclase ; but on powdering a fragment very minutely and examining the structure of the cleavage-fragments with crossed nicols under a high power, it was found that it partook rather of the nature of a microcline-perthite ; and that on similarly treating one of the pink felspars from the granite (p. 148) the two were identical.

Lithia-mica is a commonly occurring mineral in the quartz-veins of greisens, and it is needless to quote authorities on that head : this also is the case with topaz. The lithia-mica may have been formed *in situ* by metasomatic action on the granite-face : the topaz may have been formed similarly, or it may have been deposited by heated water or vapour, percolating through, and deriving the necessary material from, the freshly-formed greisen. This latter seems the more probable view, since, from the poor development of the greisen at the extremity of the tongue, it would appear that fluorine was not present in sufficient quantities for the topaz to have been formed by metasomatism on the wall of the fissure.

As for the microcline-perthite, since we know that secondary growths of felspar[1] occur both in igneous rocks and in sandstones, as also we know that the recrystallization of felspar-grains has taken place as a result of thermal metamorphism in arenaceous rocks,[2] it is not a matter for surprise to find that the pink felspar of the granite has been redeposited, presumably by the same means as those that effected the deposition of the topaz, in the 'bedding-planes.' Nor, when we consider that the fluorine and boron were present in less quantities at this particular spot, as is shown by the freshness of the biotite and the poor development of greisen, is it a matter for wonder that the felspar has been allowed to recrystallize here, but not nearer the main mass of granite. The topaz and felspar were probably deposited at the same time, approximately, as that when the fissures of the 'bedding-planes' were filled with quartz in the main mass and the northern part of the tongue.

[1] C. R. Van Hise, Am. Journ. Sci. ser. 3, vol. xxvii (1884) p. 399.
[2] A. Harker, 'Petrology for Students' 2nd ed. (1898) p. 286.

When the quartz was deposited, a question which involves the source and mode of deposition of the ores which it contains also (namely, cassiterite, wolfram, mispickel, and copper-pyrites), cannot be discussed here. No material advance has, it is believed, been made on the well-known opinions of Daubrée[1] and, in later years, of Prof. Vogt,[2] in the matter of the formation of tin-ore, and consequently, seeing how intimately the cassiterite is associated with the other minerals formed, the actual chemical reactions which took place along the 'bedding-planes.' That fluorine and boron were the principal means of the metasomatism is all that we can safely say.

To conclude then :—

The Cligga-Head granite is the remnant of a much larger mass, which has been partly denuded by marine action, and partly hidden by a big north-and-south fault.

It is possible to distinguish two divisions in the granite; the main mass and the granite-tongue, throughout both of which 'bedding' is well developed.

The granite bordering the 'bedding-planes' has been altered to greisen, which, owing to the abundance of quartz, appears in the cliff-section as dark bands.

Each greisen-band contains a quartz-vein, marking the original fissure along which the metasomatism took place. These quartz-veins contain blue tourmaline and the following ores:—cassiterite, wolfram, mispickel, and copper-pyrites. They thus form tin-lodes which fall under Prof. Vogt's 'Cornish type' (*loc. cit.*) characterized by the accompaniment of copper-pyrites.

Two main reactions have taken place in the formation of the greisen: the felspars affording topaz, muscovite, and secondary quartz; the biotite affording brown tourmaline, magnetite, and secondary quartz. The fact that no tourmaline has been formed from the felspar, owing to the presence of abundant fluorine, distinguishes this greisen from such granite-modifications as luxullianite and trowlesworthite.

The original quartz contains inclusions of minute, pale blue tourmaline-prisms, sometimes orientated to the prism- and pyramid-planes. They were original constituents of the granite. The original quartz-grains also prove to have been enlarged by the deposition of secondary quartz in optical continuity. The secondary quartz has further caused the original grains to appear as if they possessed a crystal-outline.

The fluorine and boron had not so great an effect on the extremity of the granite-tongue as on the main mass. This is shown by the poor development of greisen and the freshness of the biotite, which sometimes forms veins of porphyritic crystals.

[1] Ann. des Mines, vol. xx (1841) p. 65, & 'Études Synthétiques de Géologie Expérimentale' vol. i (1879) p. 28.

[2] Zeitschr. f. Prakt. Geol. vol. iii (1895) p. 145.

Lithia-mica has been formed in the fissures of the 'bedding-planes' in the tongue; and topaz and microcline-perthite, which occur in the mass, have been redeposited there by percolating water or vapour.

The greisen is an example of Prof. Vogt's 'pneumatolytic' action on thoroughly acid rocks,[1] resulting in the formation of tinstone-lodes, as contrasted with pneumatolytic action on syenitic rocks[2] with the production of zircon, etc., and on basic rocks,[3] as, for example, olivine-gabbro, with the production of chlor-apatite and scapolitization of the felspars.

My heartiest thanks are due to those who have assisted me in the course of the preparation of this paper, especially to Dr. J. S. Flett, M.A., F.G.S., of H.M. Geological Survey.

Discussion.

Prof. Seeley said that the tourmaline-problem would require examination over a wider area before the colour could be explained. In the Portsoy district, where tourmaline-crystals were commonly enclosed in quartz, the central part was sometimes brown and the external part blue, or occasionally a blue crystal might have a brown casing. Tourmaline was also abundant in pegmatite in the Rubislaw Quarry at Aberdeen; but here one side of a crystal might be brown and the other blue, the limits of colour being irregularly defined. In neither case was there evidence of such reactions as the Author found at Cligga Head.

Dr. Flett, while heartily congratulating the Author on his paper, remarked that the questions with which he dealt were very interesting and very difficult. In regard to the stanniferous veinstones, so far as his experience went, the blue tourmalines were always later than the brown. The problem of their origin was a large one, and we required to know more before finally solving it. So far as he could make out, the process of filling up the stanniferous veins followed closely on the consolidation of the granite, and the rock-succession was somewhat as follows: (1) pegmatite; (2) greisen; and (3) second deposition of tinstone, quartz, etc. Copper-bearing solutions arrived at a later stage of cooling, but all these processes had long ago come to an end.

The Author said, in reply, that he wished it to be understood that he by no means regarded his inference concerning the tourmaline in the lodes as final; he himself had seen parallel growths of blue and brown tourmaline, and did not venture to elucidate the occurrence, although he thought that an explanation founded on the segregation of the magnesia, wherever it was derived, might prove feasible. On this point, which was a secondary one in his paper, he

[1] Zeitschr. f. Prakt. Geol. vol. iii (1895) p. 145.
[2] *Ibid.* vol. ii (1894) p. 458.
[3] *Ibid.* vol. i (1893) pp. 4, 125, & 257.

merely wished to state, from a study of certain slides and observations in the field, that as a general rule the tourmaline in the killas bordering the lodes and granite was brown, while that in the quartz of the lodes was blue. Although he had not found it yet, he would expect some blue tourmaline in the killas, on account of the abundance of felspathic grits; and, on the other hand, he admitted that there were exceptions to the blue tourmaline in the lodes. The Author's object in entering into this question at length was to strengthen his contention that none of the brown tourmaline in the Cligga-Head greisen was derived from the felspar, and that therein the rock differed from luxullianite and trowlesworthite. In conclusion, he expressed his gratitude for the cordial manner in which his paper had been received.

15. NOTES *on the* GEOLOGY *of* PATAGONIA. By JOHN BROOKE SCRIVENOR, Esq., M.A., F.G.S. (Read February 4th, 1903.)

[PLATE XIII—MAP.]

CONTENTS.

I. PREVIOUS LITERATURE.

APART from the papers dealing with the extinct vertebrate faunas, the following are important works on the geology of Patagonia. For further literature, see the bibliography appended to Dr. Ortmann's Report.

D'ORBIGNY, ALCIDE. 'Voyage dans l'Amérique méridionale' vol. iii: Géologie & Paléontologie. Fo. Paris, 1842.

DARWIN, CHARLES. 'Geology of the Falkland Islands.' Quart. Journ. Geol. Soc. vol. ii (1846) pp. 267–74.

DARWIN, CHARLES. 'Geological Observations.' 2nd ed. 8vo. London, 1876.

AGASSIZ, LOUIS. ['South-America Expedition.'] 'Nature' vol. vi (1872) p. 272.

ENGELHARDT, H. 'Ueber Tertiærpflanzen von Chile.' Abhandl. d. Senckenberg Naturforsch. Gesellsch. vol. xvi (1891) pp. 629–92 & 14 plates.

MERCERAT, ALCIDE. 'Essai de Classification des Terrains sédimentaires du Versant oriental de la Patagonie australe.' Anales del Museo de Buenos Aires, ser. 2, vol. ii (1896–97) pp. 105–30.

AMEGHINO, FLORENTINO. 'Notes on the Geology & Palæontology of Argentina.' Geol. Mag. 1897, pp. 4–20.

HATCHER, J. B. 'The Cape-Fairweather Beds.' Am. Journ. Sci. ser. 4, vol. iv (1897) pp. 246–48.

HATCHER, J. B. 'On the Geology of Southern Patagonia.' Am. Journ. Sci. ser. 4, vol. iv (1897) pp. 327–54.

NORDENSKJŒLD, OTTO. 'Tertiary & Quaternary Deposits in the Magellan Territories.' Am. Geol. vol. xxi (1898) p. 300.

HATCHER, J. B. 'Sedimentary Rocks of Southern Patagonia.' Am. Journ. Sci. ser. 4, vol. ix (1900) pp. 85–108.

HATCHER, J. B. 'The Lake-Systems of Southern Patagonia.' Am. Geol. vol. xxvii (1901) pp. 167–73.

MORENO, FRANCISCO P. 'Explorations in Patagonia.' Geogr. Journ. vol. xiv (1899) pp. 241, 353.

STANTON, T. W. 'Reports of the Princeton University Expeditions to Patagonia, 1896–1899, vol. iv, pt. 1: The Marine Cretaceous Invertebrates.' 1901.

ORTMANN, A. E. 'Reports of the Princeton University Expeditions to Patagonia vol. iv, pt. 2: Tertiary Invertebrates.' 1902.

II. THE SEDIMENTARY ROCKS.

The latest classification of the Patagonian sediments is that by Mr. J. B. Hatcher, who conducted the Princeton University Expeditions. Previous to its appearance, M. Alcide Mercerat, of Buenos

Aires, published a classification based on his observations in Southern Patagonia. Both are summarized here in tabular form :—

CLASSIFICATION OF PATAGONIAN SEDIMENTS, AFTER M. ALCIDE MERCERAT.

System.	*Series.*	*Period.*
Pleistocene.	Terrestrial Deposits.	Pleistocene.
Téhuelche.	Upper Téhuelche. Pebble-Bed. Basalt-mesetas.	Pliocene.
	Middle Téhuelche. Lignitiferous sands, with *Ostrea Remondi.*	Miocene.
	Lower Téhuelche (*Ostrea Torresi*).	
Santa Cruz.	Upper Santa Cruz (*Ostrea Ferrarisi*).	
	Lower Santa Cruz (*Ostrea Bourgeoisi*).	Eocene.
Patagonian.	Upper Patagonian (*Ostrea patagonica*).	
	Lower Patagonian and *Pyrotherium*-Beds.	Laramie.
Guaranitic.	Conglomerates and lignitiferous sands.	
	Red sands with Dinosauria.	Cretaceous.
	Limestones, with *Inoceramus (?)*	

MR. HATCHER'S CLASSIFICATION.

Shingle Formation.	Pleistocene.
Cape Fairweather Beds.	Pliocene.
Santa Cruz Beds.	Miocene.
Patagonian Beds.	
Upper Lignites.	Oligocene.
Magellanian Beds.	
(Unconformity.)	Eocene.
Guaranitic Beds.	Cretaceous.
Lower Lignites.	
Variegated Sandstones.	
Upper Conglomerates.	
Belgrano Beds.	
Lower Conglomerates.	
Gio Beds.	
Mayer Shales, with imperfect remains of *Ammonites.*	Jurassic.

During several months' travelling in Patagonia I had opportunities of gaining some knowledge of the geology of the country ; but, owing to the great distance traversed in the time, I found that it was impossible to study the stratigraphy satisfactorily, except in the neighbourhood of Santa Cruz, where a few weeks were spent. In that district the Patagonian and the Santa Cruz Beds are excellently exposed, as also is the 'gravel-formation,' which, in order to avoid any confusion, will be referred to hereafter as the Téhuelche Pebble-Bed.

Fig. 1 (p. 162) represents a section of the Patagonian Beds[1] at Entrance Point, at the mouth of the Rio Santa Cruz. The divisions mentioned by Darwin in 'Geological Observations' lie respectively between the 272-foot and 220-foot levels, the 220-foot and 159-foot levels, the 159-foot level and the talus-marks. These beds were also examined 18 miles up stream, on the estancia of Don Pedro Richmond, where they yield a rich invertebrate fauna. The section here does not present so varied a lithological character as that at

[1] For the fauna of the Patagonian Beds, see Dr. Ortmann's Report above quoted.

Fig. 1.—*Section 1 mile west of Entrance Point, Rio Santa Cruz.*

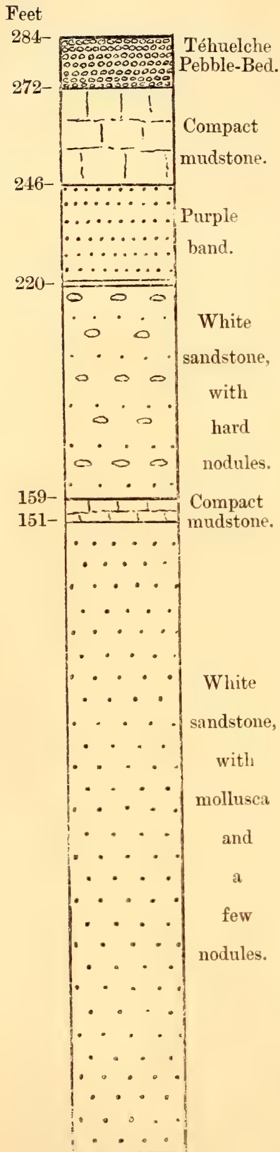
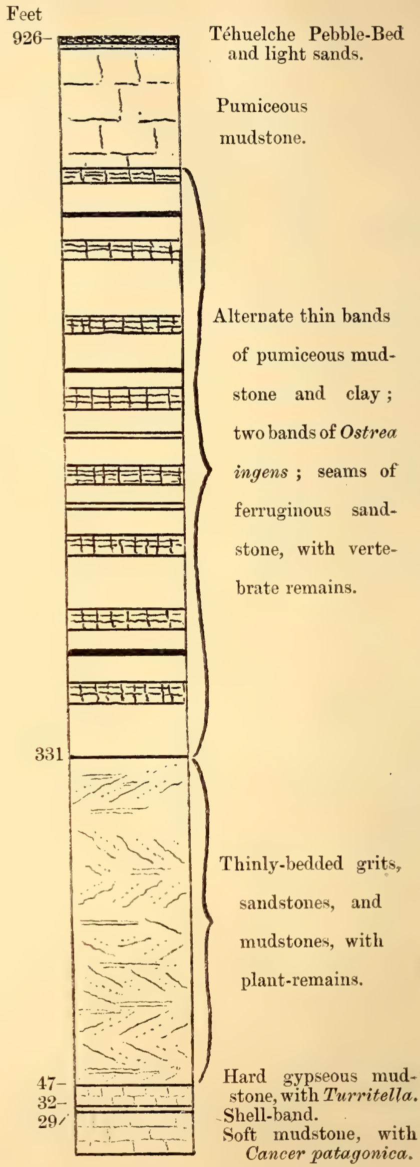


Fig. 2.—*Section at Monte Leon, from sea-level to the first pampa.*



Entrance Point, being apparently the inland continuation of the lower 150 feet only. It consists of dull green sandstone with some argillaceous matter, and contains several layers of calcareous concretions arranged along the bedding-planes, which are only seen to be dipping slightly southward by following the beds along the coast of the Atlantic. The sandstone is highly felspathic, both orthoclase and plagioclase being abundant. The grains are distinctly worn, and comprise, in addition to the felspars, quartz, hypersthene, a monoclinic pyroxene, and a small amount of zircon. The presence of hypersthene, which forms the bulk of the heavier minerals and is quite fresh, together with the plagioclase and monoclinic pyroxene, is remarkable, since it suggests that the Patagonian Beds are partly derived from contemporaneous andesitic tuffs or older tuffs and lavas.

The top of the Patagonian Beds is excellently exposed in the cliff-section, on a part of the coast at Monte Leon, well known locally as the haunt of numbers of sea-lions. Fig. 2 (p. 162) is a section showing not only the Patagonian Beds, but also a thick series of estuarine deposits succeeded by the well-known Santa Cruz mammaliferous deposits.

The shell-bed, which does not extend for more than a quarter of a mile, contains abundant invertebrate remains, some of which, notably *Turritella*, are found in pockets in the overlying gypseous mudstone, where they seem to have struggled for some time against the unfavourable conditions.

The estuarine series consists of yellow and white mudstones, and false-bedded sandstones and grits. Plant-remains are abundant, but only *Fagus* could be determined; at the top of the series a few specimens of *Ostrea* were seen projecting from the mudstone-bands.

The white mudstone-bands of the Santa Cruz Beds consist to a large extent of isotropic pumiceous [1] material; fragments of felsite,[2] hypersthene, and monoclinic pyroxene also occur.

III. The Igneous Rocks.

Passing to the igneous rocks, we find that very little has been noted as to their nature, and, with the exception of the basalt-plateaux, not much is known of their distribution. I was able, during my journey, to collect specimens from the moraines bordering Lake Buenos Aires, and also to examine certain masses of intrusive rock in the territory of Chubut. But I was unfortunate in not seeing the mass at Port Desire (Puerto Deseado) described in detail by Darwin [3] as a claystone-porphyry of metamorphic origin.

At Port St. Helena a quartz-porphyry dyke occurs, which was mentioned by Darwin [4] as closely resembling the Port-Desire rock, and also the basal formations of the Chilian Cordilleras.[5] It trends east and west, is 7 miles long, and three-fifths of a mile broad. Although intruded into soft gypseous mudstones, this dyke does not

[1] Pumiceous tuff was noted by Ehrenberg in sediments farther north. See Darwin's 'Geol. Obs.' 2nd ed. (1876) p. 374.

[2] The word felsite is here used to denote fragments of the groundmass of lavas and intrusive rocks in which the minerals are too small for determination.

[3] 'Geol. Obs.' 2nd ed. (1876) p. 436. [4] *Ibid.* p. 435. [5] *Ibid.* pp. 435, 473.

stand out as a ridge, a fact which leads one to suppose that the pampas here represent a plain of marine denudation of recent date. Nor is this the only unexpected feature presented, for throughout its length the dyke is cut by a longitudinal cañadon, roughly 200 yards broad, in which is situated the estancia of Mr. Langley, an English settler who has taken advantage of the perfection of the divisional planes in the quartz-porphyry to quarry it for use in Buenos Aires as paving-stone. The alteration of the 'country' is very marked, and results in a hard red rock with occasional grains of quartz.

At Trelew a fine-grained, acid intrusive rock is being quarried for local use, as also is the case at Camerones Bay.

In the valley of the Chico de Chubut two intrusive masses were noted. One, north of Malespina, forming a boss over 40 feet high, stands by itself in the alluvial flat; it also is a quartz-porphyry. Another, some 3 miles distant to the south-west, forms a bold cliff close to the river. The latter of these two masses is remarkable for being intensely contorted, and broken by numerous minute faults. The axes of contortion and the faults trend north-west and south-east; and there is also a well-defined series of joints trending north-east and south-west. The rock is composed of folia of quartz, felspar, and a purple material resembling the groundmass of some of the porphyry-pebbles in the Téhuelche Pebble-Bed; so that there is strong reason to believe it to be similar to a quartz-porphyry in composition. Unfortunately the 'country' in the immediate vicinity of the bosses is covered by alluvium, therefore it could not be ascertained whether it is metamorphosed or not. If the two bosses are of the same age, it is strange that one should be undisturbed and the other contorted. The mass is too big to be regarded as the marginal portion of a large boss, where a structure approaching this (but for the faults) might conceivably be produced. At Port St. Helena the intrusion is undoubtedly later than the Tertiary deposits, but this mass must be earlier, since no one has noted in the sediments of the Chico-de-Chubut Valley any disturbances sufficient to produce the degree of contortion observable in the porphyry.

Acid intrusive masses occur on the shores of Lake Buenos Aires, and the moraines in that region show that others must occur in the Cordilleras overlooking the lake. Intrusive masses are also met with in the southern part of Patagonia.

The specimens of igneous rocks selected from the moraines of Lake Buenos Aires for slicing represent the more commonly-occurring types, and, since they present no important details, it will suffice merely to enumerate them, as follows:

Biotite-granite, with abundant microperthite, and in one specimen a little tourmaline.
Hornblende-granite.
Quartz-mica-diorite, with abundant apatite.
Gabbro.
Hornblende-picrite.
Quartz-porphyry.
Rhyolites, with characteristic structures.
Trachytes.
Olivine-dolerite, with ophitic structure.
Olivine-basalt.
Acid tuffs.

The hornblende-granite forms a link between the biotite-granite and the quartz-mica-diorite, and, judging from the profusion in which these three types occur together on the northern shore of the lake, it may be safely assumed that they have been derived from a common complex where one type merges into another.

In view of the abundance of hypersthene in the sediments of Eastern Patagonia, it is remarkable that no hypersthene-andesites nor tuffs containing hypersthene-fragments were found in the moraines. This leads to the conclusion that the irruptions of granite and porphyry in this part of the Cordilleras have masked these rocks, and that they took place after the deposition of the Santa Cruz Beds and prior to the formation of the Téhuelche Pebble-Bed: in fact, they were probably contemporaneous with the formation of the tectonic valleys of the Cordilleras to be noted later.

IV. The Basalt-Flows.

The enormous extent of the basalt-flows was noted by Darwin, who found the end of the mass 67 miles from the mouth of the Rio Santa Cruz.[1] I saw them exposed in the valley of the Chico de Santa Cruz and at many points nearer the Cordillera, from which chain they are cut off abruptly by a longitudinal depression well seen between Lake Buenos Aires and Lake Pueyrredon, and, according to Dr. Moreno, of tectonic origin. Another basaltic area is found in the region of Lakes Colhuapé and Musters. The traveller journeying from Chubut to Colhuapé first encounters these flows in the valley of the Rio Chico de Chubut, some 15 miles from the outlet of that river from Lago Colhuapé. Around the lake the basalt, which overlies light-coloured sediments, baked at the junction, is carved into curious prominences visible for a great distance. Masses of basalt occur again in the valley of the Senguerr and at the junction of the Rivers Senguerr and Mayo. Whether anyone has definitely connected this basaltic area with that which lies to the south-west, having its western limit under the Cordilleras, cannot be ascertained; but, seeing that this region was in earlier times the seat of orogenic movements, the remains of an ancient mountain-chain being found near Lake Musters,[2] it is not improbable that it represents a distinct but contemporaneous outburst.

The lavas of the other, and better-known, area were first seen by me on the shores of Lake Buenos Aires. On the northern shore only in one place was basalt found *in situ*, near and east of Colle Piramide. At the point of entrance of the Rio Fenix into the lake another small mass appears, beautifully glaciated, and to the eastward the plains are dotted with basalt-erratics. On the southern shore, at a considerable altitude above the lake, is a vast plateau of basalt. Sloping gently eastward, it extends without a break as far as the valley in which the Arroyo Gio flows, and southward as far as the gap leading to Lake Pueyrredon. Beyond these breaks are a series of plateaux,

[1] 'Geol. Obs.' 2nd ed. (1876) pp. 381–85 & fig. 34 (p. 379).
[2] F. P. Moreno, Geogr. Journ. vol. xiv (1899) p. 367.

all basaltic, no doubt at one time continuous, but now broken up by valleys. In one valley, between those of the Deseado and the Charcamac (the latter a small stream flowing from the plateau), I had an opportunity of examining the section laid bare, in height about 80 feet, a measurement which only represents part of the total thickness of the flows. The section showed three bands of compact rock separated by vesicular basalt, which probably represent three distinct streams of lava. In the dense basalt, olivine, augite, and plagioclase were visible, with minute flakes of a mineral which was probably weathered brown mica. Some of the plagioclase-crystals were partially re-fused. The vesicular basalt also showed the above minerals, with the exception of the mica. A rough columnar structure was observable in places.

In the valley of the Chico de Santa Cruz both sides show sections of the same basalt-flow for a great distance; in fact, on the left bank, to within 70 miles of Santa Cruz itself in a direct line. On the right bank the flow does not extend so far, owing to the convergence of the valley of the Chico with that of the Rio Santa Cruz. In the former valley are four remarkable isolated masses of basalt: one, Sierra Oveja, I did not pass close enough to speak of with authority, but Mr. Hatcher states that it is igneous.[1] This is the first mass seen when descending the valley from the Cordilleras. The others, Sierra Ventana, Baleria Sud, and Baleria Norte, are composed entirely of basalt similar to that described above. The most conspicuous is Sierra Ventana, a mass between 200 and 300 feet high, forming one of the rare landmarks in the dreary East Patagonian landscape. It rises sharply to a point, suggesting by its form a lofty German mediæval castle, and has, close to the summit, a natural window-like aperture, from which the hill takes its name.

That the wide-spreading basalt-flows were produced by the usual type of eruption, that of small vents along lines of fissure, there can be little doubt. Dr. Moreno has recorded craters at several localities under the foothills; I saw them on the plateau overlooking Lake Buenos Aires; but to the east evidence of their existence is not definite, so that it is possible that the flows may have travelled for considerable distances, and that the vents were restricted to a line (or lines) of fissures immediately adjacent to the foothills of the Cordilleras, with a north-and-south trend. Mr. Hatcher has described Sierra Oveja and Sierra Ventana as volcanoes,[2] and stated that the latter consists of vesicular and slaggy basalt. Of Sierra Oveja I cannot speak, for the reason stated above; but the configuration of the valley at this point led me to conclude that Sierra Ventana, like Baleria Sud and Baleria Norte, is but a remnant of the plateau spared from the denuding powers of the river.

A noteworthy point, with regard to the angle of inclination of the flows, is mentioned by Darwin,[3] that of the abrupt rise in the

[1] Am. Journ. Sci. ser. 4, vol. iv (1897) p. 339.
[2] *Ibid.* pp. 339 & 350.
[3] 'Geol. Obs.' 2nd ed. (1876) p. 384.

vicinity of the Cordilleras. This can be plainly discerned when travelling from Lake Buenos Aires to the Chico de Santa Cruz, and is so constant that one is not so much inclined to attribute it to subsequent tectonic disturbances, as to regard it as the original angle at which the lava solidified. It is even possible that the line along which the angle changes is the line where the lava plunged into the sea.

Concerning the age of the basalt, nothing definite can be said in this paper, as it was impossible to study for a sufficiently long time the strata underlying it. M. Mercerat places it in the Upper Téhuelche; Darwin considered the flows on the Rio Santa Cruz to be contemporaneous with the beds that have been called 'Upper Patagonian' by M. Mercerat. Judging from evidence that I have seen, the outburst took place prior to the tectonic disturbances which produced the great transverse valleys of the Cordilleras, and before the glaciation of the eastern slopes of that range. The latter point is proved by the abundance of basalt-erratics now lying on the surface of the ground near the Cordilleras; the former contention is upheld by the fact that the disturbances which produced the depression wherein Lake Buenos Aires lies have faulted down a portion of the plateau on the southern shore, mentioned above, to the level of the lake at the mouth of the Rio Fenix.

V. The Téhuelche Pebble-Bed.

This 'gravel-formation' was first met with in the Colony of Chubut. Thence to the Rio Mayo, either the bed itself, or pebbles in the valleys derived from it, are always to be seen. Later, in the vicinity of Santa Cruz, there were good opportunities of studying it. Before describing the petrological characters of its constituents, I must mention that at Port Madryn, in the Golfo Nuevo, which was actually the first spot at which I saw the 'gravel-formation,' it is probable that M. Mercerat would refer the deposit to one of the older pebble-beds, since the matrix is arenaceous and contains an *Ostrea* resembling '*O. patagonica*,' which it was unfortunately impossible to preserve.[1] The bed in question occurs in a low cliff on the beach, and underlying it is one of the mudstones mentioned by Darwin.[2] Rolled fragments of the mudstone occur in the pebble-bed, but it may be that this demonstrates nothing more than a local check of short duration in the deposition, since at Monte Leon I observed a similar phenomenon in the continuous series of false-bedded grits and mudstones. If, then, this pebble-bed belongs to the Upper Patagonian, it cannot be considered in connection with the Téhuelche Pebble-Bed, except to note that it contains pebbles of quartz-porphyry similar to those in the younger deposit.

On ascending to the pampas above the valley of the Rio Chubut a sheet of gravel is found to cover the surface. The thickness could not be ascertained, but I am led to believe, by the alternate bare

[1] Mercerat, Anales Mus. Nac. Buenos Aires, ser. 2, vol. ii (1896–97) p. 115.
[2] 'Geol. Obs.' 2nd ed. (1876) p. 373.

patches and 'pools' of pebbles which sometimes occur, that the cap is very thin and not continuous. With the pebbles numbers of *Ostreæ* are found, smaller than those obtained at Port Madryn, and probably derived from the underlying mudstone. A poor natural section occurs at Pozo del Sur, on the road to Camerones Bay, in the bed of one of the small streams caused by the melting snow in spring-time. Doubtless many more such sections exist, but since the materials have been rearranged by the stream and mingled with fragments of the mudstone underneath, they are of little interest. On the Chubut pampas the pebbles are chiefly quartz-porphyries with a reddish matrix; this type prevails for quite 18 leagues. On approaching Mr. Greenshield's estancia in Camerones Bay a yellow quartz-porphyry is seen to take the place of the red. It first appears in quantity in the Cañadon Salado, and becomes more and more abundant as one approaches the estancia; in fact, south of Cañadon Davis, between Cañadon Salado and the estancia all the larger pebbles, some as big as a man's fist, are of this type. In some of the porphyry-pebbles quartz and felspar are equally developed; in others, one or other of these phenocrysts predominates. At Camerones I noted, besides, pebbles of breccia, banded tuffs, and occasionally of rhyolites. On the pampa at Malespina, west of Camerones Bay, dark, spherulitic, and glassy pebbles were noted in addition to the porphyries (probably acid lavas), and also breccias containing portions of these lavas. In a cañadon hard by a large granophyre-pebble was found, and several others of agate. In the valleys of the Chico de Chubut and Senguerr the pebbles remain of the same type, but on the Rio Mayo a change sets in—biotite-granite and gneissose rocks appearing.

At Santa Cruz the river has piled up a bank of the pebbles by the settlement; among them foliated and contorted rocks, hornblende-gneiss, rhyolites, and tuffs are common. At Monte Leon quartz-porphyries are, as in every locality so far noted, the most conspicuous element; they vary in colour, being yellow, brown, or more rarely red. One pebble of a sheared porphyry was collected; of the other pebbles the following are typical:—A holocrystalline rock in which the quartz and orthoclase have crystallized simultaneously, rich in epidote, but not revealing the nature of the original ferromagnesian mineral; a light-green pebble, apparently a highly-altered and sheared sediment; a beautiful spherulitic pebble, with nuclei of quartz and one or two grains of orthoclase; a large brown pebble showing bands of felspathic material, disturbed by several small dislocations, recalling the rock found *in situ* on the Rio Chico de Chubut; a green gneissose rock; and a coarse-grained hornblende-granite, with pink orthoclase.

A good section of the Téhuelche Pebble-Bed is exposed in the cliffs bordering the Rio Santa Cruz below the tide-limit on Don Pedro Richmond's estancia, where it occasionally exceeds a thickness of 10 feet. The height of the cliff above high-tide mark is not more than 150 feet at the spot where I examined the section. Here the calcareous cement mentioned by M. Mercerat is well

shown. Not only does it figure as a loose cement, but in places it is further developed as a homogeneous layer some inches thick; and in a small cañadon leading to Señor Richmond's estancia I observed a similar deposit of much greater thickness containing bad casts of mollusca, but owing to the amount of talus I could not make sure of its relation to the pebbles. At Monte Leon the matrix is more argillaceous, and contains little of the calcareous cement. Nowhere did I see it in distinct bands.

The pebbles are, everywhere on the eastern coast and for some distance inland, when *in situ* and not directly exposed to the atmosphere, perfectly rounded. On the pampas in the Territory of Chubut those on the surface retain their rounded form, but on the pampas south of Santa Cruz, where the frosts are more severe, angular pebbles are not uncommon. To see that this is not the original form of the pebbles when deposited it is only necessary to go to the nearest cañadon in which a section is exposed, where they will be found perfectly rounded. Nowhere do they show ice-scratches, nor does their mode of deposition suggest a glacial, but rather an aqueous origin. Sometimes, as in the valley of the Chico de Chubut, they appear to have been slightly polished by the action of the wind.

VI. The Origin of the Téhuelche Pebble-Bed.

The glacial theory of the origin of the Téhuelche Pebble-Bed has not met with by any means general acceptance. M. Mercerat states that only in the river-valleys, where the denuded pebbles are heaped together, could a glacial origin be mistakenly ascribed.[1] Mr. Hatcher shows how the marine beds at Cape Fairweather pass up into the Pebble-Bed imperceptibly.[2] Darwin considered that it was of marine origin.[3] On the other hand, the waterworn appearance of the pebbles cannot alone be taken as a fatal objection to the glacial theory, for Mr. Philip Lake has informed me that certain old moraines in the Himalayas are composed entirely of well-rounded pebbles, without any signs of scratching. That the Pebble-Bed on the eastern coast can owe its origin directly to glacial action is, in my opinion, impossible, since in that case pebbles of basalt, over which any glacier coming to Santa Cruz from the Cordilleras would have to pass, would be mingled with the porphyries. As it is, no one has noted them in any locality near the coast; but Darwin mentioned their presence some way up the Rio Santa Cruz, due probably to the mingling of the Pebble-Bed débris in the valley with the pebbles transported from the basalt by the river to varying distances below the termination of the flow, the greatest distance being 30 miles in the case of vesicular basalt.

Although not of glacial origin itself, the fact that the Pebble-Bed passes into true glacial deposits in the south cannot be doubted. Among others Dr. Nordenskjœld has pointed this out, and gives as

[1] Anales Mus. Nac. Buenos Aires, ser. 2, vol. ii (1896–97) p. 113.
[2] Am. Journ. Sci. ser. 4, vol. iv (1897) p. 246.
[3] 'Geol. Obs.' 2nd ed. (1876) p. 225.

his opinion that the bed was 'laid down by big rivers whose sources were immense glaciers, and which, flowing through country with a comparatively level surface, often altered their course.' He points out that the bed cannot be said to cover the pampas entirely, but if we assume the modern rivers to have approximately the same course as their bigger predecessors, then it is possible to explain why sections of considerable thickness are found in the valleys.[1]

To me it seems that the origin of the Pebble-Bed must have been complex. The glaciers which scoured the eastern slopes of the Cordilleras have deposited at the heads of the Patagonian rivers a vast amount of morainic material consisting of the rocks already described. Porphyries are among them, but nowhere in sufficient quantities (in my experience) to supply the requisite amount for the bed on the eastern coast. On the melting of the snow and ice the torrents would wear the fragments, and distribute them in fans over a considerable area. Subsequent subaërial denudation might go far to produce the appearance of a continuous and stratified deposit. At this time the coast-line lay certainly farther west than at present; on that point there seems to be no difference of opinion. It may even be that the coast-line had not yet receded far enough eastward since the outpourings of basalt, to make the terminations of those flows dry land. Supposing this to be the case, and admitting that the torrents had brought the morainic material to the coast-line, the sea would further distribute them, not only along its shores, but over the bottom, as has been shown to be the case on the present shore-line,[2] so that an uniform layer of pebbles would be deposited over the basalt, which, as the sea receded more to the east, would (if the supply of material was sufficient) extend over the limit of the flows. This hypothesis will perhaps permit of the presence of the hornblende-gneiss, granitic, and rhyolitic pebbles east of the basalt without basalt-pebbles, but it must be frankly admitted that it is not convincing. Yet the alternatives, that they have been derived from masses *in situ* on the east of the basalt, or from older pebble-beds deposited before the basaltic eruptions, draw even more on the imagination, since no such masses as the former have been yet discovered, and our knowledge of the distribution and contents of the latter is insufficient.

M. Mercerat, when speaking of the Pebble-Bed on the east of the basalt, says that he follows Darwin's opinion, founded on observations at Port Desire, that the porphyry-pebbles have not been derived from the masses found in that region *in situ*.[3] On the other hand, Darwin admitted[4] that they may have come partly from rocky ridges in the central districts of Patagonia. That masses of quartz-porphyry, not necessarily forming ridges, do exist in greater number than was known at the time of the voyage of the *Beagle* is now certain, and the objection that the colours of the pebbles do

[1] Am. Geol. vol. xxi (1898) p. 303.
[2] 'Geol. Obs.' 2nd ed. (1876) p. 214.
[3] Anales Mus. Nac. Buenos Aires, ser. 2, vol. ii (1896–97) p. 114.
[4] *Op. supra cit.* p. 224.

not exactly match those of the masses near which they are found cannot be very serious, seeing how the pebbles may have been washed along the old shore-line and then again disturbed by the present rivers. That the porphyry-pebbles have been in part derived from the Cordilleras is quite probable; they occur on the southern and northern shores of Lake Buenos Aires, in the bed of the Rio Fenix, in that of the Rio de los Antiguos, on the floors of the valleys from the Fenix to the Belgrano—indeed everywhere I saw them, but never, under the Cordilleras, bearing such a ratio to the other granitic, gneissose, and rhyolitic pebbles as to admit of those mountain-chains being the sole source from which the pebbles in the bed on the eastern coast were drawn. There really seems to be no valid reason why the portion of the bed east of the basalt should not have been laid down by the action of a sea gradually receding, but with long enough breaks for the formation of the steps which lead from one pampa to another as they rise to the Cordilleras, the material being chiefly derived from islets of quartz-porphyry.

It may be objected that, since the pebble-bed (mentioned on p. 167) at Port Madryn contains the same pebbles as the Téhuelche Pebble-Bed, and yet occurs in such close association with strata which have elsewhere (at Port St. Helena) been metamorphosed by the intrusive mass of quartz-porphyry, it is improbable that the material could have been derived from that mass or any mass of the same date of irruption. To this there are two answers:—Firstly, the relative age of the mudstones at Port Madryn and Port St. Helena is not clear: those at the latter locality may quite possibly be older and owe their position to disturbances of the crust; secondly, seeing that in the valley of the Chico de Chubut a foliated and faulted mass occurs not far from a mass of similar composition, but showing no signs of stress, it is impossible that the igneous masses of the Chubut territory were irrupted at the same time.

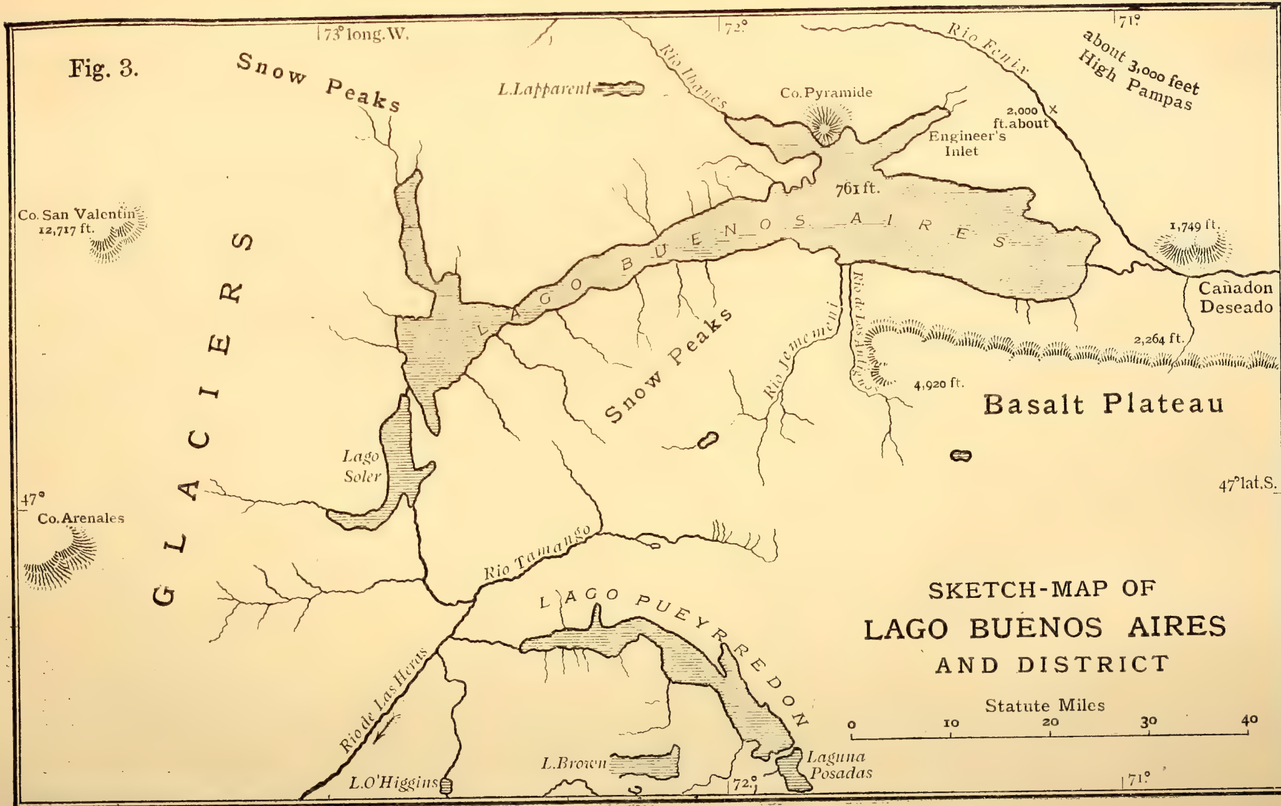
Can the Téhuelche Pebble-Bed have had a purely fluviatile origin after the requisite material had once been detached from the Cordilleras by the glaciers? This would necessitate the transportation of the gneissose and granitic rocks found at Santa Cruz and Monte Leon from the Cordilleras by river-power only. Then it follows that numbers of basalt-pebbles would be brought with them, whereas they do not exist. Again, Darwin cites, as an instance of the insignificant transporting power of the Rio Santa Cruz, which has a speed of 5 knots, the fact that dense basalt could not be found in its bed at a greater distance than 10 miles from the end of the flows, nor vesicular at a greater distance than 30.[1] How, then, could the granitic and gneissose pebbles be transported from the moraines? If a stronger stream is brought into being to do the work, it affords also a stronger argument for expecting basalt-pebbles at the coast.

M. Mercerat says that the pebbles increase in size towards the Cordilleras.[2] This is a generalization to which I would not commit myself, unless I had seen a great deal more of the

[1] 'Geol. Obs.' 2nd ed. (1876) p. 224.

[2] Anales Mus. Nac. Buenos Aires, ser. 2, vol. ii (1896–97) p. 114.

Fig. 3.



SKETCH-MAP OF
LAGO BUENOS AIRES
AND DISTRICT
Statute Miles
0
10
20
30
40
73° long. W.
72°
71°
47°
47° lat. S.
Snow Peaks
Snow Peaks
GLACIERS
Co. San Valentin
12,717 ft.
Co. Arenales
L. Lapparent
Rio Ibanes
Co. Pyramide
Rio Fenix
about 3,000 feet
High Pampas
2,000 ft. about
Engineer's Inlet
761 ft.
LAGO BUENOS AIRES
1,749 ft.
Cañadon Deseado
2,264 ft.
4,920 ft.
Rio de Los Antiguos
Rio Jemeneni
Basalt Plateau
Lago Soler
Rio Tamango
LAGO PUEYRREDON
Rio de Las Heras
L. O'Higgins
L. Brown
Laguna Posadas

Téhuelche Pebble-Bed than is the case, and taken a large series of observations to that end. But it may be said that the general impression left on my mind is that there is a great irregularity in the size of the pebbles; that there is no definite increase or decrease in any direction; and that, if these pebbles were called to witness to the course of an ancient stream, they would only mislead.

Recent marine shells were seen on the pampas and elsewhere at various points: a *Patella* at Dos Pozos, between Chubut and Camerones, with the colour preserved; two more at Monte Leon, at an altitude of 325 feet; and two big specimens of *Voluta* on the banks of the Rio Santa Cruz, 18 miles from its mouth. Yet I saw no occurrences which entirely precluded the possibility of human agency, although such an explanation is improbable. However, anyone who has read Darwin's 'Geological Observations' cannot doubt that there is sufficient evidence in South America for the elevatory movement necessary for the formation of the Téhuelche Pebble-Bed by marine agency.[1]

VII. The Drainage-System.

The drainage-system of Patagonia, comprising the rivers that flow eastward over the pampas and innumerable lakes, vast basins like Lago Buenos Aires not only penetrating into but even piercing the Cordilleras, moraine-ponded lagunas, pampa-pools (fresh and salt), and the two isolated lakes Colhuapé and Musters, affords a study as varied as it is interesting. For economic purposes the supply under the Cordilleras is abundant, but north of the Rio Santa Cruz and east of the foothills it is very poor. Springs are so scarce on the pampas inland that travelling across them is very difficult, and even impossible in places without guides, when once the snow-pools have dried up. Near to and on the eastern coast, however, there is an abundance of small streams welling from under the steep banks which lead from one pampa to another, a fact which makes sheep-farming possible along a narrow belt bordering the Atlantic.

Of the lakes, Lago Buenos Aires calls for description, not only because it is the largest in Patagonia—being 75 miles long and, in the eastern portion, 12 to 15 miles broad—but also because it lies in an enormous transverse valley cutting through the Cordilleras, and drains into the Pacific by a stream connecting with Lake Soler, which is in turn drained by the Rio de las Heras. This drainage to the west is all the more remarkable, since by far the greater part of the water is supplied by rivers rising on the eastern side of the Cordilleras. The height of the lake, as ascertained by Señor Waag, of the Argentine Boundary Commission, is only 761 feet above sea-level. Seeing that on either side there are peaks exceeding 12,000

[1] Mr. Hatcher has noted a large erratic block in the valley of the Chico de Santa Cruz, close to the junction with the Chalia or Sheuhuen; the nature of the block is not mentioned. It may be suggested that the granitic and gneissose pebbles have been brought to the eastern coast by floating ice; but the number of these pebbles, their regular distribution, and, in my experience, the total absence in the Santa Cruz district of exceptionally large pebbles of any sort in the Pebble-Bed strongly militate against this theory.

feet (Colle San Valentin 12,717 feet, and Colle San Lorenzo 12,008 feet), this insignificant altitude enables one better than any laboured description to realize the magnitude of this rift through the Cordilleras.

I spent some weeks on the shores of Lake Buenos Aires, but was never able to proceed farther than Colle Piramide on the north or the Rio Jememeni on the south; so that, although the snow-peaks beyond the western limit of the lake were visible through the rift on clear days, I have to rely on information supplied by the Boundary Commission for the western, and, it is believed, the most interesting part.

An excellent panoramic view of the lake is obtained from the high pampas above the Rio Fenix, whence the eye can command the enormous basalt-plateau stretching eastward and ending abruptly on the west above the gorge, part of the longitudinal depression of the Cordilleras, containing the two rivers Jememeni and Los Antiguos; the red foothills, furrowed with torrents; and the vast snow-fields and peaks of the Cordilleras themselves, rent by the chasm which contains the central and western portion of the lake.

Here, above the Fenix, one grasps the key of the geological structure of Patagonia: the plateau, the culmination of the wind-swept table-lands which rise step by step from the Atlantic coast; the longitudinal depression, formed by a series of faults cutting off the plateau from the Cordilleras; and the transverse valley, breaking the continuity of the mountain-chain itself, as though it had been cut with a knife.

On descending from the pampas, a wilderness of morainic débris is entered, dotted with large erratics and cut by ravines where the melting snow had drained down to the Fenix. Crossing this river, which, at the point where I passed, flows through a broad alluvial flat perched on the steep slope between the lake and the pampas, another region of moraine, sculptured (with no advantage to the scenic effect) into low conical hills, is encountered, at first rising some 650 feet above the bed of the Fenix, then leading down by clearly-marked terraces to the swamps and dreary tracts of scrub, sand, and erratics, which form the last 500 feet of the descent to the lake. Continuing along the shore to the south-east, a ridge formed by a pale-red, acid intrusive rock was crossed, and a slightly richer area of grassy swamps entered, cut off from the lake by a fringe of blown sand. These dunes are broken for a short distance at the point of entrance of the Rio Fenix by the small outcrop of glaciated basalt already noted, and continue southward for another 2 miles, giving way then to a long stretch of morainic material on the southern shore, traversed by several streams from the basalt-plateau above. East of the small outcrop of basalt are muddy lagunas only a few inches deep, lying on the delta of the Fenix, and marshy land which rises to a ridge forming an arc of a circle round the head of the lake at a distance of between 4 and 5 miles. Through this ridge the Fenix has cut a steep ravine. Beyond are arid pampas, with erratic boulders, rising to the Cañadon Deseado, where the valley of

the Fenix makes a sharp turn to the north-north-east. Still farther east are more pampas, which ultimately abut on an extension of the basalt-plateau not far beyond Laguna Pajé.

The history of Lake Buenos Aires may be read from the evidence afforded by the shores thus briefly described. First, at some date subsequent to the basaltic eruptions and prior to the extensive glaciation, a huge transverse valley with an approximately east-and-west trend was formed by a series of faults. It would have been safe to assume this, even if direct evidence had not been seen, for no one would venture to attribute such a chasm to river-erosion. But direct evidence is there, in the isolated mass of basalt, occupying less than half a square mile of the delta of the Fenix; a cliff bordering the lake 50 feet high; a roche moutonnée slightly lower; and several glaciated pavements hidden among the bushes. There is no other basalt *in situ* visible nearer than the great plateau 8 miles to the south, which is over 3000 feet higher, therefore it cannot be looked on as an older and distinct flow; indeed there seems little reason to doubt that this is a remnant of a large faulted area of the plateau. What it was that caused this valley to be filled with water cannot be definitely stated, seeing that no geologist has yet visited the western end of the lake; but, taking into consideration the greater extent of glacial conditions in former times, and the presence of large glaciers to-day on Colle San Valentin and Colle Arenales, it is a reasonable conjecture that it was owing to glacial ponding on a large scale. Dr. Moreno[1] speaks of the lake as a fjord, an expression which must be taken to imply that he considers it to be an arm of the Pacific raised above sea-level. Although the resemblance of the narrower portion to a fjord is striking, no mention has yet, we believe, been made of marine shells on the terraces or on the shores. No doubt the general elevatory movement in Chile and the Argentine affected the area in question, but it was probably owing to the Cordillera being unable to bear the strain of that movement at this particular point that the transverse, and also the longitudinal, valley was formed, so that the depression may not have acquired its greatest development until some period had elapsed after the first upheaval, the entrance of the ocean being thereby rendered unlikely.

The terraces mentioned by the same author in the western, and those seen by me in the eastern, portion of the lake, together with four raised beaches identical with that now at the head of Engineer's Inlet, show that the original level was higher than at present, and has been gradually decreasing. Its greatest extent has not yet been determined; but since, as Dr. Moreno has shown, the ancient outlet, in common with those of other Patagonian lakes, was to the Atlantic, the height of the land on the east shows that it may have been 700 feet higher than at present. The breaking-down of the barrier at the western end of the lake would cause the waters to fall to successive levels and prevent them at the same time from flowing eastward, diverting them instead to the Pacific.

[1] Geogr. Journ. vol. xiv (1899) p. 354.

During the latter part, at least, of the history of Lake Buenos Aires, the lake and the slopes on either side were covered by ice coming from the Cordilleras. The form of the roche moutonnée and the scratches on the glaciated pavements at the mouth of the Fenix show the direction of its advance to have been due eastward. This ice-sheet it was that deposited the vast accumulations of morainic detritus when it melted; moreover, it is due to the irregular surface of the débris that numerous muddy pools are scattered over the lower slopes.

The two lakes, Musters and Colhuapé, are situated in the midst of the more northerly basaltic area, the former under the hills believed to represent an old Patagonian mountain-chain, the latter more to the east. A companion of mine saw Lake Musters and gathered valuable information as to its topography. I myself, during the short halt at the settlement of Colhuapé, had perforce to confine my attention to the eastern lake. Great doubt appears to exist about the topography of these two lakes and their rivers, even to the extent of the names of the lakes being interchanged. Whatever may have been the original design of the discoverers, there is no doubt that now the inhabitants of the Welsh settlement there and in Chubut call the eastern lake Colhuapé, the western Musters. So far as could be gathered from personal observations and local information, the following are the leading features: a ridge, extending from below the southern shore of Colhuapé northward, cuts off the one lake from the other; there is no communication between them visible. Musters is fed by a river entering it at the north, the origin of which is not clear. Lago Colhuapé is supplied by the Rio Senguerr, which, flowing from the Cordilleras at first with a south-westerly course, makes a bold sweep round the hills to the west of Lake Musters, and then, leaving that lake on the left, flows on into Colhuapé. No outlet for Lake Musters is known, but Colhuapé is drained by the Rio Chico de Chubut, on the east.

Lago Colhuapé is fast being silted up. Unlike that of Musters, its water is muddy and shallow, and already one-third of the basin in which it lies has been converted into a rich alluvial flat, on which the Welsh and other settlers have established themselves. The form of the lake does not suggest an old river-valley. It lies in a vast amphitheatre, overlooked on the east by the broken edge of a basalt-plateau, and on the west by the ridge that separates it from Lake Musters and the ancient mountain-chain beyond. If ever the physical geology of these lakes is worked out in detail, it will not be surprising to me to find that they also owe their origin to tectonic disturbances of the same date as those which formed Lake Buenos Aires.

VIII. The River-Valleys.

The valleys of the rivers which flow across the pampas are all clean-cut troughs, the walls of which rise to the flat land above at an angle varying from 30° to 40°. Terraces, well marked on

either side, occur along their lower reaches, often, as in the case of the Chico de Santa Cruz, forming 'valley-pampas' of considerable extent. The great width and depth of the valleys is strangely disproportionate to the streams which flow through them, even taking into account their swift currents. In earlier times, however, the accumulation of surface-drainage flowing through these valleys was much greater, the subsequent decrease being due to a diminution of rainfall, the lowering of the levels of the lakes under the Cordilleras and the consequent diversion of their waters (in some cases at any rate, to the Pacific), and the capture of streams which originally flowed to the Atlantic, by others feeding the lakes.

So great has been the decrease that now some river-beds are quite dry but for pools, and others contain water only in the spring. The great cañadon of the old Rio Salado, north of the Chico de Santa Cruz, is the best example of the former case; the smaller cañadon of the same name, north of Camerones Bay, is a good example of the latter.

I was fortunate in crossing the head of the great Cañadon Salado on my way to Santa Cruz. The only water flowing now into it is a small stream rising under a basalt-plateau, the Rio Olnie (or Olin), which after a few miles loses itself in a series of pools. North of the point at which the Olnie enters is a moraine-covered pampa, where was once a sheet of ice moving a few degrees east of south. This sheet apparently met, in the cañadon, another coming from the direction of Colle Belgrano, with the result that a barrier of morainic material, in which obsidian figures largely, was formed across the course of the old river. On riding along the top of this barrier it was found that the river had never surmounted it, the only signs of flowing water being small gullies formed by the melted snow in spring running westward into a horseshoe-shaped lake about 1 mile across, and quite 200 feet below the ridge. This little lake is an ideal example of glacial ponding, and represents all that is left of the Rio Salado; that it is still diminishing was shown by the series of perfectly defined beach-marks above it, more than ten of which were counted. Flowing into it from the west were one or two torrents, but I could not see any trace of an exit; maybe that surface-evaporation and filtration through the glacial débris account for this. Interesting as this case of ponding is, it is nevertheless evident that it cannot be responsible for the drying-up of the Rio Salado, for had not other causes been at work, such as those suggested above, the river would have filled up the cavity, surmounted the barrier, and flowed on. That other agencies have been at work may be also inferred from the fact that south of this lake is another cañadon, joining the Cañadon Salado below the barrier, and of considerable size, which is quite dry, except perhaps when the snow is melting in spring.

Señor Ameghino has expressed his opinion that the valleys of the pampas are fault-valleys, and it would appear that Dr. Moreno is also inclined to this view. Valuable as are the works of these authors, it is believed that, as yet, no convincing evidence on

this point has been produced. Judging from the evidence of the valleys traversed during my journey, I agree with Mr. Hatcher that they have been formed by denudation. Darwin, it is true, has given good reason for considering the valley of the Rio Santa Cruz an old sea-strait, and Dr. Moreno says that that of the Rio Gallegos is of a similar nature; but Darwin does not say anything as to the valley of the Santa Cruz being a fault-valley. Nothing was seen in the valleys mentioned above to suggest such an origin; indeed, the presence of the outlying basalt-masses—Sierra Ventana, Baleria Sud, and Baleria Norte—in the valley of the Chico de Santa Cruz, masses which are at the same level as the basalt on the valley-wall, are direct evidence to the contrary.

How great a part marine denudation took in the formation of the valleys north of the Santa Cruz I am not prepared to say; but when we take into account the fact that morainic material has blocked the head of the great Cañadon Salado, and (if the evidence of the Téhuelche Pebble-Bed has been read aright) the close association of the moraines, pebbles, and the former greater extent of the sea, it appears at least probable that these valleys are continuations of older valleys which existed before the sea receded; and that, since we know from evidence supplied by Darwin that the recession was gradual and interrupted, the sea took a part in moulding the upper terraces of the valleys over a considerable portion of their lengths. Again, when, in addition to the possible marine action, we consider the former greater volume of the rivers and the increase in denuding powers afforded by the general upheaval of the land, the difficulty of the disproportionate size of the valleys and the present rivers is reduced, if it does not vanish.

IX. Summary.

The Patagonian Beds are well developed on the banks of the Rio Santa Cruz. They contain fresh plagioclase and hypersthene.

The top of the Patagonian Beds is marked at Monte Leon by a shell-bed and gypseous mudstone, the latter with stunted *Turritellæ*.

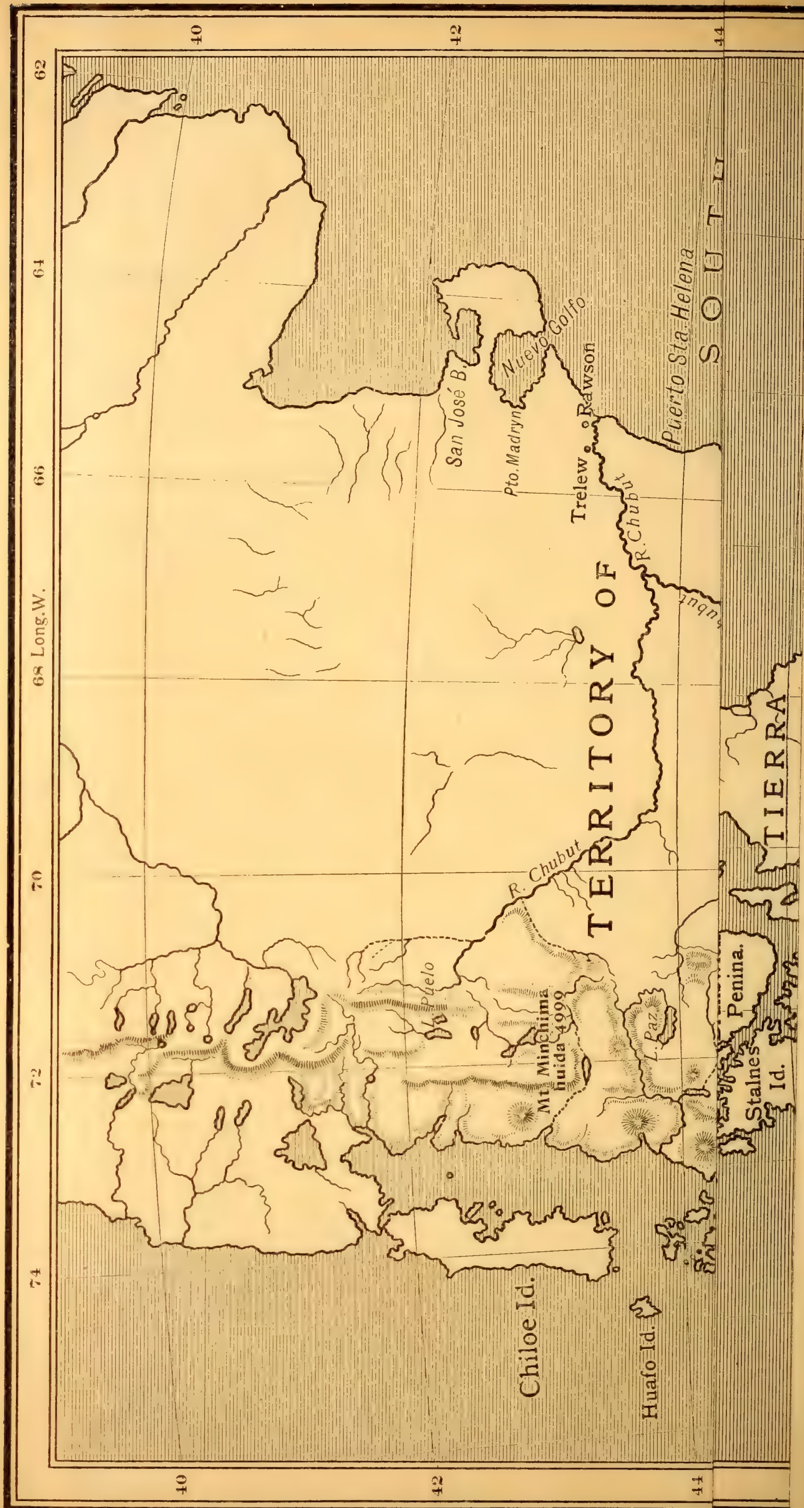
A series of estuarine beds with plant-remains, and showing evidence of oscillation of the land-surface, intervenes between the marine Patagonian Beds and the terrestrial Santa Cruz Beds.

The Santa Cruz Beds consist of mudstones and blue clay, with bands of ferruginous sandstone and of *Ostrea ingens*, Zittel. The mudstones contain a quantity of pumiceous material and some fresh hypersthene.

The presence of fresh hypersthene indicates that, while the Patagonian and Santa Cruz Beds were being deposited, either ejections of andesitic tuffs were taking place, or part of the sediment was derived by denudation from older andesitic rocks.

Numerous intrusions of quartz-porphyry occur in Patagonia, especially in the Chubut Territory, where two bosses were seen—one foliated and faulted, the other undisturbed, showing that the intrusions cannot have taken place at the same date.

[The name 'Rio Mayo' has been omitted in the above map. It is the river flowing eastward and westward, 30 miles north of lat. 46° S., and joining the Rios Guenguel and Senguerr.]


62
64
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68 Long. W.
70
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74
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42
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San José B.
Nuevo Golfo
Pto. Madryn
Rawson
Trelew
Puerto Sta. Helena
R. Chubut
TERRITORY OF
SOUTH
TIERRA
L. Puelo
Mt. Minchimahuida 4999
L. Paz
Penina.
Stalnes Id.
Chiloe Id.
Huafo Id.

Specimens of igneous rocks from the moraines under the Cordilleras comprise biotite-granite, hornblende-granite, quartz-mica-diorite, gabbro, hornblende-picrite, quartz-porphyry, rhyolites, trachytes, ophitic olivine-dolerite, olivine-basalt, and acid tuffs.

If hypersthene-andesites exist, they have been masked by the later acid igneous rocks, which were probably contemporaneous with the formation of the transverse depressions of the Cordilleras.

The basalt-flows are of enormous extent, and came from vents along lines of fissure trending north and south. The basalt near Lakes Musters and Colhuapé marks a distinct but contemporaneous area of eruption.

The basalt is older than the transverse valleys of the Cordilleras, and older than the Téhuelche Pebble-Bed.

No single agency can account for the formation of the Téhuelche Pebble-Bed. It is due to glacial, to fluviatile, and also to marine action.

Part of the porphyry-pebbles in the Téhuelche Pebble-Bed have been derived from the masses of quartz-porphyry east of the basalt-flows.

Lake Buenos Aires, draining into the Pacific, lies in a tectonic valley cutting through the Cordilleras. Its original volume was much greater than at present, and its outlet was to the Atlantic.

The disproportionate size of the valleys crossing the pampas to the streams that they contain is owing to decrease of rainfall, capture of tributaries, and to the share that possible marine denudation played in their formation.

An ideal case of glacial ponding was found at the head of the great Cañadon Salado.

No evidence was found to show that the valleys crossing the pampas are fault-valleys. The outliers of basalt in the valley of the Rio Chico de Santa Cruz are direct evidence to the contrary.

My thanks are due to my friend, Mr. H. H. Thomas, M.A., F.G.S., who pointed out the true nature of the hypersthene in the sandy Patagonian Beds, and the similarity of the mineral constituents to those of the volcanic dust of Martinique; also to those who gave me their assistance in South America, foremost among whom are Señores Hauthal, Santiago Roth, Dr. F. P. Moreno, and Señor Waag; also to Mr. Roger Campbell, whose generosity made pleasurable my stay at Monte Leon; and to many others whose hospitality I enjoyed.

EXPLANATION OF PLATE XIII.

Sketch-map of Southern Patagonia, on the scale of about 100 miles to the inch, partly based on that drawn up by Dr. F. P. Moreno, by kind permission of the Secretary of the Royal Geographical Society.

16. *The* FIGURE *of the* EARTH. By WILLIAM JOHNSON SOLLAS, M.A., D.Sc., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford. (Read January 21st, 1903.)

SOME of the more striking features of our planet are apt to escape attention if our studies are made upon charts without the assistance of a 'globe.' Thus the remarkable alignment of many volcanoes, volcanic islands, coast-lines, and even mountain-chains along circular arcs does not seem to have excited the interest which might otherwise have been expected. An arc-like form is not infrequently alluded to, but the almost precise correspondence of some great terrestrial features with a circular form seems to be generally overlooked. As an example, the chain of the Aleutian Islands may be cited: it is certainly one of the most perfect. If a circle be swept out on a terrestrial globe with its centre in lat. 6° N., long. 177° W., its circumference passing through one of the islands of the festoon will traverse nearly all the rest and extend through the length of the Alaskan peninsula. (See Al in fig. 2, p. 183.) The correspondence is so precise as to suggest that it must have some real physical meaning. The numerous mighty volcanoes which characterize the region point to the existence of an extensive subterranean reservoir of lava, and to discontinuity of the earth's crust, in the form of a circular crack. It is difficult, as we look upon this part of the globe, to avoid the impression that we have before us the remains of a spherical dome or blister, which has broken down along circular and radial fractures, the islands standing over a circle, the coasts of the Kamchatkan Sea marking irregular radial splits. Deep sea exists outside, not far removed from a region regarded by Prof. Milne as the origin of many of the earthquakes which shake the whole crust of the earth.

The East Indies present another, almost equally close correspondence, but on a much grander scale. The centre of this arc is situated about 15° lat. N., 118° long. E., immediately west of the island of Luzon: the arc itself commences in Burmah, and continues past the Andaman Islands, the extremity of which it just touches, extends then through the Sunda Islands, grazes Java, traverses Jindana and the north of Timor, and finally passes parallel to the north-western coast of New Guinea and to the Ladrones, which lie somewhat to the east. Numerous smaller circles may be drawn concentric with this, showing a remarkable correspondence with the trend of the islands and coast-lines of the region.

The sudden inflexion of the Malayan arc off Timor Laut through the Banda Isles is an interesting discordance, not without parallel, and will be alluded to later. The leading features of the islands which correspond more or less, not to a peripheral, but to a radial direction, do not strictly follow the radii of the circle, but are often curves and more or less excentric, while some, like that ending in

Celebes, and another in Borneo, are bent round near their termination into approximate correspondence with the trend of the circular arcs.

A third example is afforded by the western shore of the southern part of North America; the centre in this case is situated in Missouri, near lat. 37° N., long. 91° W. The arc is closely coincident with the coast of California and Mexico as far as Guatemala, ending in a region which is the fruitful parent of world-shaking earthquakes. (See A in fig. 2, p. 183.)

Other instances, quite as excellent in their way, but on a smaller scale, might be cited, though for our present purpose it will conduce to brevity if we point to some less perfect correspondences. The northern part of South America is one of these: a centre situated in lat. 1° N. and long. 65° W. affords a circle which follows approximately the Andes of Peru, Ecuador, and their continuation into New Granada: (see C in fig. 2). Similarly, a centre in lat. 18° N., long. 3° W., gives a circle which more or less coincides with the contour of Western North Africa: (see Af in fig. 1, p. 182).

The great Alpine-Himalayan chain might at first sight be regarded as far too irregular to submit of reduction to geometrical form, but the case is not quite hopeless. The Himalayan chain itself is remarkably circular, its centre lying in lat. 42° N., long. 90° E. A circular arc having its centre at about lat. 69° N., long. 89° E., sweeps through the Caucasus to join the Himalayas, the intermediate chains between swaying symmetrically on each side of it. A second great arc, with its centre close to Iceland in lat. 69° N., long. 18° W., falls upon the Atlas range, in complete coincidence, and also upon the Crimean segment, at the termination of which it meets and cuts the great Caucasian curve: (see I in fig. 1, p. 182). A smaller circle from the same centre is nearly tangential to the Northern Alps and the Carpathians.

The centre in North Africa already mentioned affords a circle which runs through the Betic Cordillera, and another on which the Pyrenees lie; the latter passes nearly symmetrically through the Tyrrhenian Sea to traverse the site of Etna. This circle and the three previous ones, which we may call the Atlas, Caucasian, and Icelandic circles, enclose a lozenge-like space, within which the folding of the Apennines, Alps, Carpathians, and Balkans has taken place. Where the African overlaps the Atlas circle, the sudden inflection of the Atlas guiding-line to that of the Betic Cordilleras makes its appearance. In a similar way an Australian circle, having its centre in the Australian bight, passes through the length of New Guinea, and, where it cuts the grand East Indian arc, produces the well-known inflection which terminates in Ceram: (see Au in fig. 2, p. 183).

The important question, for which we have now prepared the way, will naturally be raised, whether it may not be possible to bring the chief of the imaginary centres which have been indicated into some general connexion. The two best-marked examples of a

circular form are those of the East Indies and the Aleutian Isles. If we sweep a great circle to pass through the centres of these, it will be found to run symmetrically through the bordering seas of Asia as far as Alaska, traversing the centre of the Japanese arc on

Fig. 1.

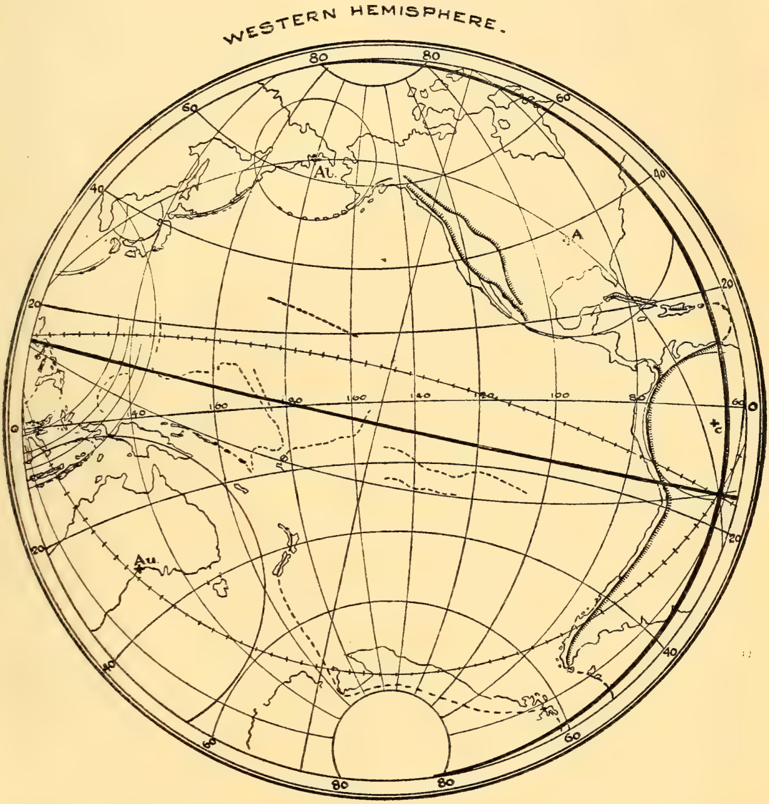
Stereographic projection of the Earth, the pole of projection 6° north of the Equator in the Eastern Hemisphere.

The great circles indicated by thin continuous lines are a system of three, having their points of intersection 90° apart, and one of which passes through the centres of the East Indian and Aleutian arcs. The great circles distinguished by crossed lines -+-+- are a similar system, and one of them passes through the centre of Suess and the East Indian centre. The great circles shown by thick continuous lines are a third similar system, and one of them passing through the East Indian centre bisects the angle formed by the other two great circles which pass through the same centre. My best thanks are due to my friend Mr. H. N. Dickson, who kindly constructed for me the network of circles of latitude and longitude on which the stereographic projection is based.

[The draughtsman has accidentally omitted the +Cau indicating the position of the Caucasian centre in the above figure. It lies on the same circle as +S, 5 'crossbars' north-west of it.]

the way, but not those of the other festoon islands. In its further progress it crosses the Mesozoic deposits of North America, along the borders of the great chain of inland lakes, passes very close to the Californian centre, cuts across the extremity of the Appalachians,

Fig. 2.



and leaves the continent along the middle line of Florida. It extends through the middle of the Caribbean Sea, enters South America, passes near to the South American centre, and runs out to sea through the southernmost part of Brazil. It passes near the Sandwich Isles, parallel with the coast of the Antarctic continent near Enderby Land, but remote from it, and returns to the East Indian centre without touching Australia, though it is almost tangential with the Australian circle.

Thus a great circle joining the East Indian and Aleutian centres takes a course in remarkable correspondence with the general trend of the great zone of Pacific weakness. Such a correspondence can scarcely be a matter of mere accident. One pole of this great

circle will be found to lie near Kufra in the Libyan Desert, the other in the Pacific, south of the Society Islands, in lat. 35° S., long. 152° W.

If a globe be turned towards the observer so that the African pole is in the centre facing him, he can scarcely fail to discover an unexpected symmetry. The African continent has the appearance of a vast dome, surrounded by seas, and separated from the Pacific, which is spread over the greater part of the opposite hemisphere, by an irregular and interrupted belt of land which runs round the entire world almost midway between the African and Pacific poles. The course of two great circles joining these poles, one passing through the East Indian centre and the other at right angles to the first, may be remarked upon in passing. The first passes with close parallelism off the south-eastern guide-line of Luzon, farther on it agrees in trend with the Solomon Isles, passes through Vanua Levu of Fiji, is on the whole concordant with the general run of the Austral Isles and the Low Archipelago, strikes South America in the middle of the great inflection of the Andes of Peru, crosses this continent and enters Northern Africa, which it traverses obliquely from west to east with a general parallelism to the North African foldings, and passes very near to the West African centre; it crosses the northern ends of the Red Sea and Persian Gulf, extends along the depression just south of the Himalayas, which is of great importance as the site of a buried axis of disturbance affecting the Indian geodetical observations; passes out to sea through the Gulf of Tongking, having on either side of it the symmetrically-placed curves of Cochin China and the Hongkong coast, and so back to the East Indian centre.

The second great circle, drawn at right angles to this, crosses the Antarctic continent from the south of Victoria Land to the north of Enderby Land, coincides with the South African coast from Cape Coriantes to Sofala, then enters the continent and runs north-north-westward between Lakes Nyasa and Tanganyika, cuts the Equator in long. 30° E., pursues a course parallel with the shores of the Red Sea, but remote from them, leaves the continent along the coast of the Desert of Barka, and enters Italy by the Gulf of Taranto, crosses the Adriatic, Bavaria, and the North Sea, passes not far north of the Icelandic centre, and enters Greenland by its eastern salient angle near Scoresby's Sound. It then intersects the great Pacific circle in North America somewhat west of long. 120° W. and north of lat. 60° N., crosses the Pacific, runs parallel with the north-north-easterly trend of New Zealand, but as much as 14° away from the coast, and so returns to the Antarctic continent.

The symmetry of the terrestrial figure, which we have just glimpsed, has been reached in total disregard of the great Eurasian flexures; but these can by no means be left out of account, for they are only second in importance to those of the Pacific belt. Lake Baikal may be regarded as the arc of a small circle, which circumscribes a region determined by Suess as the

morphological centre of Asia. Let us join this by the arc of a great circle passing through it and the East Indian centre, and complete the circle. It will be found to pass so close to the Caucasian centre, which determines one great arc of the Eurasian folding, as to be practically coincident with it, and it passes equally near the great Icelandic centre which determines the Atlas-Crimean arc. This circle may therefore be regarded as the directive circle for the Eurasian folding, just as that joining the East Indian and Aleutian centres was for the Pacific belt. In its further course, after crossing the Atlantic it runs through the whole length of South America, crosses the Antarctic continent, and just touching the west coast of Australia, with the northern half of which it is coincident, returns to the East Indian centre.

The two main directive circles, the Eurasian and Pacific, intersect at an angle of 39°; if now we finally draw another great circle midway between them, bisecting this angle we shall obtain a mean directive, the pole of which will determine as high a degree of symmetry as is discoverable in the features of our planet. This pole is situated on the great circle passing from north-north-west to south-south-east through Africa, near the sources of the White Nile, 6° north of the Equator. It lies on the same great circle as that which we had provisionally obtained, but 21° nearer the Equator. The axis of terrestrial symmetry thus passes through the middle of Africa on the one side, and of the Pacific Ocean on the other.

This result acquires additional value from the conclusions of geodesists, who find that the terrestrial figure which best represents the results of geodetical measurements gives to an equatorial diameter passing through Africa a length appreciably in excess of one directed at right angles to it. The point where this axis intersects the surface is given by Capt. Clarke as being situated in long. 14° 23′ E., but by Gen. Schubert in long. 41° 4′ E. Our morphological pole is situated midway between these points, in long. 28° E., lat. 6° N. If a charted globe be mounted on an axle corresponding with the morphological axis, and an equator to this axis be drawn round it, the symmetrical distribution of land and sea will be readily apparent. Africa, as we have seen, forms the summit of one hemisphere; the smallest circle that will circumscribe it has a centre 2 or 3 degrees west and north of the morphological pole; points separated by 120° upon it are the Cape of Good Hope, Cape Blanco, and Kedji in Baluchistan. If we regard this circle as marking the boundaries of the original African dome, now fractured and fallen in, we perceive a certain amount of symmetry still persisting in the remainder, the extension southward to the Cape of Good Hope forming one arm of a trilobed mass, that to the east-north-east a second, and that through Arabia and Persia a third, but this is broken across by the Red Sea and the Persian Gulf. Between these lobes we have, in the case of the first and second, a great piece of the dome swallowed up by the Atlantic, only small volcanic islands like Ascension and Tristan d'Acunha rising over its

site; between the first and third a similar great segment has disappeared into the Indian Ocean, but larger fragments project above the sea-level, such as Madagascar, and more numerous volcanic islands, such as Mauritius and the Seychelles. Finally, the segment between the second and third is only partly submerged beneath the sea, its site being occupied by folded mountain-chains and great inland seas, like the Mediterranean and Black Sea. A falling in of an imaginary dome has been spoken of, but this is not a necessary deduction; a trilobed form may have been original, and the fracturing of which we possess independent evidence may have affected portions of these lobes.

Outside the margin of the imaginary dome is an encircling sea for nearly two-thirds of its circumference, but over against the northern one-third symmetry is at present disturbed by continental land, which, however, was not in existence, at all events to the same extent, in the early stages of terrestrial development.

The boundary of the circum-African seas is afforded by the great Pacific belt of continents. Commencing with the Antarctic mass, which lies symmetrically about our mean directive circle, we pass to South America, which projects a little more towards the African pole; then to North America, which sways completely to the Pacific side of the directive; next to Asia, which swings over to the African side; and lastly to Australia, which crosses over to the Pacific side. Thus the continental belt is an undulating one, but its most recent mountain-foldings lie almost wholly on the Pacific side of the directive, and nearly tangential with it, the great exception being that of the Eurasian festoon of arcs which lies on the African side. The belt is also interrupted, and that more or less symmetrically, as will be seen from figs. 1 & 2, pp. 182–83.

Beyond the continental belt lies the Pacific Ocean, covering nearly an entire hemisphere, with an approximately symmetrical distribution about the western morphological pole. A section taken through the globe along a great circle, of which the morphological axis and the East Indies-South American axis are two of the diameters, would have roughly a pear-shaped form.

In attempting to discover an explanation of this figure, our thoughts naturally revert to Prof. G. H. Darwin's theory of the evolution of the earth-moon system, and Prof. Darwin has himself attempted to correlate the continental distribution with tidal effects. The Rev. O. Fisher also has suggested that the Pacific Ocean might represent the 'scar' left on the separation of our satellite. It is probable that the tidal deformation which gave origin to the moon was not the last of its kind; it may well have been followed by others, which, without producing a second satellite, may yet have given to the earth a figure approaching the dumb-bell-like form, and of this a reminiscence may be retained in its present shape.

The moon must itself have produced a tidal effect, and could scarcely have been without influence of another kind on the primæval atmosphere, which for some time after the origin of the

moon exerted a pressure on the earth's surface of 5000 lbs. to the square inch. A permanent cyclonic system would exist over that region of the earth which immediately faced the moon, and this may have had much to do in determining the general distribution of atmospheric pressure over the earth's surface. This again may have assisted in determining the distribution of those depressions of the general level which we imagine to have initiated the ocean-basins. The oceans themselves weighting those portions of the crust over which they accumulated may have helped to preserve something of its original form; but this has undergone very considerable modifications, chiefly through the breaking-down of the greater protuberances. The position and extent of the subsiding areas would depend upon the strength of the crust and the slope of its inequalities. That the fractures by which at some stages re-adjustment has taken place have frequently been circular arcs is shown by observation, and there is much evidence to suggest that such fractures have frequently preceded as well as followed the folding-up of a mountain-chain.

This study, although it has long occupied my attention, is far from being as complete as it might easily be made; but I am led to submit it to the Society at the present stage by finding that similar but in some respects much more exactly-expressed ideas have lately been brought forward by Mr. J. H. Jeans in a memoir read before the Royal Society on December 4th, 1902, the preliminary abstract of which appears in the Proceedings of that Society, vol. lxxi, p. 136. Mr. Jeans has treated the subject mathematically, and concludes that the 'pear-like shape,' as he happily expresses it, might very possibly have been possessed by the earth at the time of its consolidation; he suggests that Australia may represent the 'stalked end' of the 'pear,' the depths of the surrounding ocean its 'waist,' and the land-hemisphere its 'broad end.' The morphological axis would have one pole near the British Isles and the other between New Zealand and the Antarctic Ocean. This correlation is less symmetrical than that which has been imagined in the present contribution, and in one respect reverses it, for we have supposed the Pacific to cover the broad end of the pear, the continental belt to correspond with its sides, the Indian, Atlantic, and Mediterranean Oceans with its waist, and Africa with the stalked end. This reversal, however, is of less importance than the recognition of a uniaxial symmetry.[1] On this point we seem to be in complete agreement, and it is not a little singular that two persons approaching the subject from such extremely different points of view should have reached essentially similar conclusions.

[1] [Since this paper was read Mr. Jeans and I have corresponded by letter on this point. His view with regard to the broad end is evidently the right one, it must be represented by the land-hemisphere. The small end will therefore correspond to the oceanic floor from which the islands of the Central Pacific rise, 'the mightiest of all the submarine buckles of the earth-crust,' Lapworth, Presid. Address to Sect. C, Rep. Brit. Assoc. 1892 (Edinburgh) p. 705.—*W. J. S., March 16th, 1903.*]

Discussion.

The President said that the subjects considered by the Author in this paper, though rarely dwelt upon by the geologist, came very naturally within the purview of the science. As he had himself often dealt with some of them, mainly from the point of view of present phenomena and present causes, he would refrain from joining in the discussion. It would be interesting to know, however, why those who inferred an original pear-shaped figure for the earth did not point out that even the present spheroid of revolution is somewhat pear-shaped—the northern or land-hemisphere, with its central Arctic depression, calling to mind the broad end of the pear, the southern oceans the waist, and the Antarctic continent the so-called 'stem.'

The Author, in reply to questions, said that he feared the most serious objection to his method was that it was empirical rather than speculative. The circular alignment of many important terrestrial features was a fact as definite as the succession of strata in a quarry: that the centres of circular systems lay upon great circles which followed the trend of lines of weakness and movement was equally certain, though no explanation had been offered of this coincidence. The correspondence of the pole of terrestrial symmetry with that of the longest equatorial diameter was a result which followed from observation. The Author had made use of centres of circles rather than tangents, because they required fewer data for their determination; their employment was new, and likely therefore to arouse distrust, but the unexpected coincidences to which their correlation led should inspire confidence. Whether the method were legitimate or not, the pear-shaped form, now that it was pointed out, became obvious to mere inspection: it was a geographical fact, and not a speculation. The question as to which was the stalked end of the pear was a matter of secondary importance, and the Author had no wish to start a controversy between the 'big-endians' and the 'little-endians.' There was no uncertainty in his own mind with regard to the present position of the stalk: its centre corresponded to the African pole of the longest equatorial diameter; but, if mathematicians authoritatively decided that it should lie at the antipodes of this, then it followed that the primitive stalk had disappeared, and the present must have been secondarily produced by a more or less symmetrical breaking-down of the broad end. The President's pear differed from the Author's and from Mr. Jeans's; its long axis extended diametrically across the Pacific belt of land. Forms of a higher degree of symmetry than that described did not seem to exist; the tetrahedron of Lowthian Green was not the same as that of Michel-Lévy, nor the latter as that of Marçel Bertrand; these ideal forms were as discordant one with the other as they were with the facts.

17. *The* Overthrust Torridonian Rocks *of the* Isle *of* Rum, *and the* Associated Gneisses. By Alfred Harker, Esq., M.A., F.R.S., F.G.S., Fellow of St. John's College, Cambridge; Geological Survey of Scotland.[1] (Read March 11th, 1903.)

[Plate XIV—Map.]

Contents.

I. Introduction: The Relatively-Unmoved Tract.

The geological literature of the Isle of Rum is not extensive. The earliest important contribution is found in Macculloch's 'Western Islands of Scotland,' and illustrates the close observation and acute reasoning which characterize that remarkable work.[2] In his small sketch-map Macculloch shows the northern part of the island and a strip along the eastern coast occupied by red sandstone, which he correctly identifies with that of Skye [Torridonian]. The rest of the island he divides among the igneous rocks, of which he distinguishes syenite [granite and granophyre], 'augit-rock' [peridotite, gabbro, etc.], and basalt and amygdaloid. In spite of the extremely crude topography of the map, the distribution of these rocks is roughly indicated, and some of the leading facts concerning their relations are set forth in the text. Since Macculloch's time no systematic account of the geology of Rum has been published. The igneous rocks, now recognized as of Tertiary age, have received some notice, and a valuable description of the peridotites in particular has been given by Prof. Judd.[3] Numerous references to Rum appear in the writings of Sir Archibald Geikie; and in 'The Ancient Volcanoes of Great Britain' he has given an account not only of the igneous rocks, but also of some of the highly disturbed strata, with associated gneisses, to be described below.[4] The present communication is the outcome of the detailed mapping of the island carried out by the writer for the Geological Survey of Scotland.

[1] Communicated by permission of the Director of H.M. Geological Survey.

[2] John Macculloch, 'A Description of the Western Islands of Scotland' . . . vol. i (1819) pp. 473–506; also map facing p. 71 of Atlas, and section on pl. xix, fig. 5. The direction of the section in that figure is incorrectly stated; the letters S. and N. should be N.W. and S.E.

[3] Quart. Journ. Geol. Soc. vol. xli (1885) pp. 354–416.

[4] 'Ancient Volcanoes of Great Britain' vol. ii (1897) pp. 349–55.

The Isle of Rum divides, on the broadest view, into a northerly moorland-tract, the highest points of which fall a little short of 1000 feet, and a southerly mountain-tract, of much bolder relief, and reaching a maximum altitude of 2659 feet. The mountains are formed of massive plutonic rocks of Tertiary age, and, as Macculloch remarked, these, at least in the eastern part of the island, overlie the stratified rocks. Torridonian strata occupy about one-half of the total area, including the northern moorland-tract and a strip along the eastern coast, as shown in the accompanying sketch-map (Pl. XIV). The highly-disturbed strata to be particularly described occur in two districts, namely, a small area in the north-western part of the island, and a more extensive belt along the north-eastern and eastern border of the mountains.

I shall give, first, a short general account of the relatively undisturbed strata which occupy the greater part of the Torridonian area. They consist principally of a monotonous succession of sandstones, dipping north-westward or west-north-westward, at angles usually between 20° and 33°; but below these emerges, on the eastern coast, a group of shales with similar dip.[1] The total thickness, as calculated from the extent of the rocks and the observed dips, is more than 10,000 feet, without any natural base or summit, and this thickness is distributed approximately as below:—

Upper group:	sandstones,	9000 feet seen.
Lower group:	shales,	1400 feet seen.

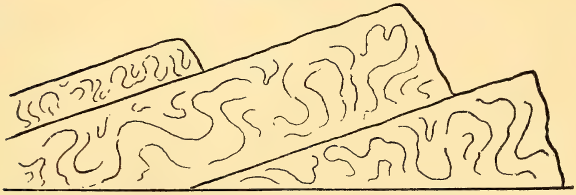
The upper group consists almost exclusively of felspathic sandstones, which have a more or less pronounced reddish colour, except where they have been bleached by metamorphism or some other agency. The texture varies from fine to coarse, many beds containing abundant small pebbles up to an inch or more in diameter. The lower group consists essentially of dark shales, of very uniform aspect where they have not been metamorphosed in the vicinity of igneous intrusions. There are, however, occasional beds of fine grey sandstone at various horizons; and some alternations of similar sandstones with shales at the summit of the group may be regarded as passage-beds to the sandstones above.

In this—which we have styled, with implied reservation, the relatively-undisturbed tract—there is, apart from some faults of moderate throw, the appearance of an unbroken succession with a gentle and steady inclination. This apparent regularity is, however, as Sir Archibald Geikie has remarked, in great measure illusory, and the estimates of thickness given above must be qualified accordingly. The stratification is in reality highly disturbed on a small scale. The sandstones, which present so monotonous a succession of steadily-inclined beds, show on closer examination in innumerable places indications of violent contortion, these indications being brought out by weathering in almost all parts of the coast-section,

[1] Macculloch ('Western Is.' vol. i, 1819, p. 481) observed these shales, but identified them erroneously with the [Liassic] shales of Loch Eishort in Skye.

and at many places on the exposed tops of the moorland-hills (fig. 1). In the shales contortion on a small scale is probably not less widespread; but it assumes a somewhat different form, which is apt to elude cursory observation. The bedding is often seen to be affected by extremely sharp zigzags, which are in fact small and very acute isoclinal folds thrust over until their axial planes are nearly parallel with the general direction of stratification.

Fig. 1.—*Torridonian sandstones on the shore at Camas Pliasgaig, Rum.*



[The appearance of regular dips is shown in strata which are nevertheless highly contorted on a small scale.]

The Torridonian strata are intersected by numerous intrusions of peridotite and gabbro, omitted in the sketch-map (Pl. XIV) in order to avoid complication, and metamorphic effects are to be observed in the immediate neighbourhood of these. The most universal and conspicuous change consists in a decoloration of the red sandstones, and the border of bleached rock surrounding the intrusive mass is often visible at a distance. In contact with the more considerable intrusive rock-masses, the sandstones have experienced metamorphism of a higher grade, involving partial reconstitution. Some consist of recrystallized quartz and felspar, the latter in subordinate amount, with some new-formed accessory mineral, usually brown mica. Not infrequently the metamorphosed rock exhibits a certain quasi-spherulitic structure, which is conspicuous on a weathered surface. A good example is afforded by the altered sandstones bordering a picrite-intrusion at Airidh Thalabhairt, on the north side of Kinloch Glen. Thin slices show that the felspar recrystallizes more readily than the quartz, and often assumes a radiate arrangement which gives the peculiar appearance just noticed. In this recrystallized felspathic aggregate the quartz-grains are often seen apparently unchanged.

Besides the small plutonic intrusions, there are, in the relatively-undisturbed Torridonian tract, very numerous dykes and sheets of basalt. These have not, in general, given rise to any sensible metamorphic effects. There are, however, certain remarkable occurrences which call for special notice, since they have a bearing on the connection between crushing and brecciation, on the one hand, and igneous injection and metamorphism, on the other.

In the tract under consideration the mechanical effects of crushing are nowhere exhibited on the scale shown in the submontane

belt, to be described below; but local brecciation is not an uncommon incident, and it usually shows a certain orderly disposition. In addition to gently inclined crush-bands, which are comparable with surfaces of overthrusting, there are others with vertical position, which are rather the analogues of normal faults. These may be connected with the great Palæozoic crust-movements of the region, or they may be of Tertiary date: in the absence of all formations between Torridonian and Tertiary, the question cannot be brought to a decisive test. These vertical crush-bands are not widely distributed, and are best studied in the Kilmory district. A good example crosses the river about a mile above the deserted hamlet: this is about 15 feet wide. Others on the neighbouring hills attain locally a greater breadth, but they usually die out in a short distance when followed along their length. They are conspicuous owing to the bleaching of the red sandstone, an effect which has been already remarked as a constant incident of thermal metamorphism, though it is not strictly confined to those circumstances. Such a brecciated and bleached band usually shows, at least in some part of its length or its width, an injection with igneous material. The invading magma has probably been an ordinary basalt, but it has been considerably modified by absorbing silica, with a certain amount of alkalies, etc., from the sandstone. Thin slices [10486, 10504[1]] show a very intimate admixture of the two rocks, abundant sand-grains in a partly-corroded state being embedded in a matrix of igneous origin. The bulk of the latter consists of slender felspar-crystals with a strong tendency to radiate arrangement, as in many of the so-called 'variolites.' The extinction-angles are quite low, indicating somewhat acid varieties, and it is probable that alkali-felspars are present. The ferromagnesian element is represented by numerous little pale-green or yellow serpentinous pseudomorphs, apparently replacing a rhombic pyroxene. Granules of epidote are also found; but it is not clear whether these are of metamorphic origin or due to subsequent alterations.

The amount of igneous material in these injected crush-bands varies greatly, affording every gradation from a basalt-dyke crowded with fragments of sandstone to a brecciated grey sandstone free from basalt; and such variation may be observed within a short distance along the length of a given band, or even across its breadth. The sandstone, when not impregnated in the manner described, is notably metamorphosed, often showing the quasi-spherulitic structure already noticed in another connection (p. 191). The metamorphism generally seems excessive, in comparison with the amount of igneous material, and there is frequently very marked metamorphism in places where no basaltic or other intrusion is to be detected. Thus, on the slope west and south-west of Loch an Tairbh, about $1\frac{1}{4}$ miles north-east of Kilmory, a pale band is traceable through the red pebbly sandstones for nearly 500 yards in a south-south-westerly

[1] These numerals in brackets are the index-numbers of the rock-slices in the Geological Survey Collection.

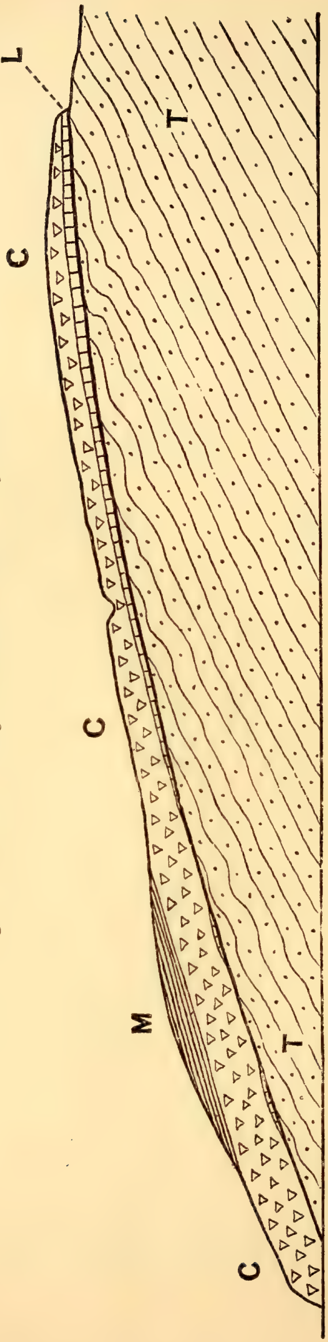
direction. In parts of its course it is merely a band of bleached and metamorphosed sandstone with more or less evident brecciation; but in other places part or the whole of its width has been injected with the basalt-magma, and reactions have ensued between the two rocks. Sometimes the igneous rock forms a matrix exceeding in amount the sandstone-fragments which it encloses. This band or dyke ranges up to 6 feet in width, and in one place it bifurcates. A shorter band a little farther north reaches locally a width of 50 feet, but only a small portion of this width, on the western border, is injected with basalt, although the sandstone is conspicuously metamorphosed throughout. Here, as in other cases, the effects are narrowly localized, the sandstone immediately bordering the crush-band showing no perceptible alteration.

Whatever be the date of the crushing, it is reasonable to assume that the igneous injection is of Tertiary age, as are the numerous basalt-dykes in the same district. The reactions noticed are precisely like those observed by the writer in many Tertiary dykes in Skye, where a basaltic magma has enclosed quartz of extraneous origin. The special interest of the occurrences here described lies in the very clear evidence of metamorphism, unmistakably of thermal type, in many parts of these crush-bands where no igneous rock is visible. To suppose that the present surface of the ground happens to coincide almost exactly with the upward limit of the basaltic injections would be a highly artificial hypothesis; for the instances are numerous, and occur at altitudes varying from 100 to 800 feet within a distance of three-quarters of a mile. The phenomena described rather suggest that, under certain conditions, notable metamorphism may be effected by some kind of solfataric agency, operating along vertical bands of rock disintegrated by crushing.

II. The Monadh-Dubh Overthrust.

Passing now to the more highly disturbed districts, we turn, first, to the small area in the north-western part of the island, where the hilly moorland named Monadh Dubh rises to an altitude of about 800 feet. A part of this is made by a cake of overthrust rocks, measuring about 1 mile by two-thirds of a mile, resting on the ordinary red sandstones of the district and cut off to the north-west by the sea. The present limits and general disposition of the overthrust mass are well displayed, the boundary being marked by an escarpment, which runs round from coast to coast, but is most prominent on the southern and south-eastern sides. The eastern boundary is highly irregular in ground-plan, depending on the details of the surface-relief, while the general inclination of the overthrust-surface does not here differ greatly from the slope of the hill. The base of the overthrust cake of rocks, marking the main surface of movement, inclines to the north-west, the dip being gentle in the higher part, but increasing seaward to about 20° (see section, fig. 2, p. 194).

Fig. 2.—*Section through Monadh Dubh, Isle of Rum.*



[The line of section is indicated on the map, Pl. XIV. Scale: 9 inches = 1 mile.]

M = Mylonite, } principally of sandstone, but
C = Crush-conglomerate, } with some limestone.
L = Crush-band, composed largely of limestone.
—— = Surface of overthrust-fault.
T = Torridonian sandstone, relatively unmoved.

The strata immediately below show to the eye no sign of extraordinary disturbance. They are red sandstones, of fine to medium grain, with a north-westerly dip of 15° to 25°, agreeing with the normal inclination throughout the northern part of Rum.

Immediately above the surface of overthrust comes a remarkable band composed largely of crushed limestone. This is mingled with sandstone, usually in a bleached condition, and the two rocks are brecciated and in part ground down together; but there are numerous unbroken lenticles of limestone, some many feet long. They contain abundant cherts, and undoubtedly belong to the Cambrian (Durness) Limestone Series, which has not been found in place on this island. The nearest known outcrops are in the Ord district of Skye, about 17 miles away to the east-north-east; but the limestone-material of Monadh Dubh has presumably come from a south-easterly direction. The calcareous band does not usually

exceed a few feet in thickness, and it is not continuous everywhere. It is best seen on the eastern side of the area. Along the southern border it is in most places wanting, though lenticles of limestone are found at intervals at the base of the overthrust rocks.

To this basement-band succeeds a much greater thickness of crush-breccia, which we may estimate at 100 to 150 feet. The material is red sandstone, only occasionally bleached. Limestone-fragments occur, but in very small proportion, though there are some larger lenticles of that rock, especially towards the base. The accumulation is more properly a crush-conglomerate than a breccia, for most of the sandstone-fragments are more or less rounded, and many of them have the shape of rolled pebbles. There is a certain amount of finer material forming a matrix, and doubtless derived from the grinding down of the angles of the fragments.

It may be remarked, in passing, that the breccia or conglomerate is in two places traversed by vertical crush-bands, partly impregnated with basalt in the fashion described in the preceding section (p. 192). This lends support to the supposition that these vertical crush-bands are quite distinct from the main system of disturbances, and are probably of Tertiary date. The bands have the same general direction as the neighbouring basalt-dykes.

Above the crush-conglomerate, and rather sharply marked off from it, is a rock which gives evidence of crushing of a more advanced kind, and may be termed a mylonite. As a consequence of the present eroded form of the land-surface, it is preserved only in the north-western half of the area, and the crush-conglomerate emerges again from beneath it along the coast-line. The thickness thus remaining is about 70 or 80 feet. The rock is of a dull brownish colour, and has a highly-schistose structure, breaking in the manner of a shale. It consists essentially of sandstone ground down and rolled out as if it had passed through a mill, as aptly expressed by Prof. Lapworth's term 'mylonite.' The fissile character is connected with the presence of new-formed mica. There is not much calcareous matter in the body of the mylonite, but small lumps of limestone are sometimes enclosed, usually indicated by cavities from which the carbonate has been removed in solution. There are also a few large lenticles of the kind noticed lower down in the section. It is remarkable that the limestone has resisted crushing down much more effectually than the sandstone.

As a minor point of interest it may be noted that, both here and in the brecciated rocks below, the fragments of Durness Limestone have not suffered the dolomitization which has affected so large a portion of that group in districts where it occurs in place. The pebbles of the same limestone in the Triassic conglomerates of Skye, Raasay, and Scalpay are also non-dolomitic.

The occurrence of this area of highly-disturbed rocks as an isolated outlier seems to preclude any direct examination of its tectonic relations, as connected with the system of crust-movements

which has produced the existing arrangement. The infraposition of the crushed limestone, and the fact that the evidences of profound mechanical disturbance become more pronounced as we pass upward in the section, suggest that the whole overthrust mass is in an inverted position beneath a more important plane of overthrusting, the position of which is not far above the present surface of the ground. Such a hypothetical major overthrust might perhaps be identified with that which traverses the centre of the island, to be described below. The belt of country neighbouring the overthrust area of Monadh Dubh shows, however, some phenomena which are not without a bearing on the subject, although the evidence obtained is only of a fragmentary nature. The red sandstones immediately beneath the crushed and displaced rocks give, as has been stated, no clear indication of any special disturbance. A little farther away, however, towards Loch Sgaorishal, occurs a narrow band, along which the rocks are highly inclined and greatly crushed. It follows a rather irregular and curved course in a general south-westerly to north-easterly direction, at a distance of 100 to 300 yards from the outcrop of the Monadh-Dubh overthrust, and can be traced for about 900 yards, dying out, so far as any palpable evidence is concerned, in both directions. It is much obscured by a boss of picrite and other smaller intrusions. Along this band the sandstone is not only brecciated, but in certain places mylonitized. Further, a certain proportion of crushed limestone is in some parts mingled with the sandstone, and there are lenticles of less crushed limestone, with cherts, like those noticed above. The appearances seem to show that the north-western boundary of this crush-band is a surface of discontinuity comparable with the Monadh-Dubh 'thrust-plane,' but inclined at a high angle. Although much more narrowly localized than in the other case, the differential movement has been of an extreme kind; and the highly-sheared sandstone, with its abundant development of white mica in parallel flakes, is a typical mylonite [10498].

III. The Overthrust Belt of the Mountain-Border.

We now proceed to consider the more extensive area of overthrust and highly-disturbed Torridonian strata in the east-central, eastern, and south-eastern part of the island, where, as shown in the sketch-map (Pl. XIV), it forms a belt along the north-eastern and eastern border of the mountain-tract. The Tertiary plutonic rocks, of which the mountains are built, consist in this district of a succession of roughly-parallel and partly-interlacing sheets or laccolitic bodies with a general inward dip. Viewed broadly, they have been intruded not far from, and usually above, the main surface of overthrusting. In places they transgress this surface, cutting into the relatively-unmoved strata below. In the western part of Rum the quasi-stratiform disposition of the plutonic masses

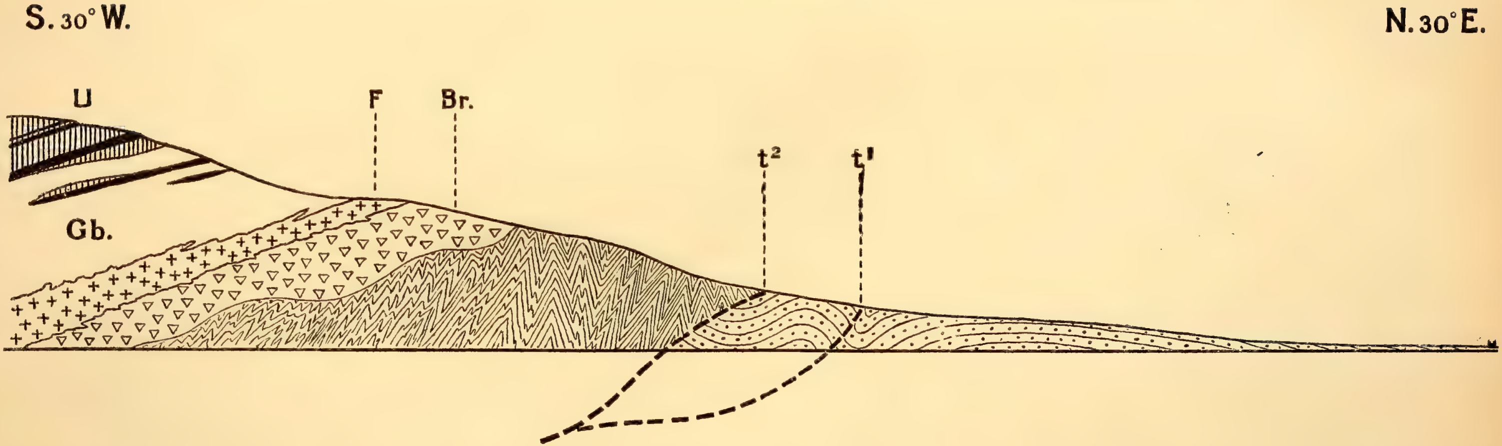
is to a great extent lost, and the intrusions, extending farther northward, entirely cut out the overthrust belt.

The curved course of the outcrop of the overthrust surface, following the outward slope of the high ground, permits us to regard that surface as having on the whole a gentle inclination towards the south-east. Regarding this course in detail, however, and in relation to the minor features of the ground, we see that the surface must be in reality greatly warped, and has in some places a rather high inclination to the horizontal. Along a great part of its length the outcrop of the overthrust runs at altitudes between 1000 and 400 feet, but in the south-east of the island it rises considerably higher inland, and at the same time comes down to sea-level at the coast. This is seen on Beinn nan Stac, where the average inclination of the overthrust surface does not differ much from the seaward slope of the hill (see section, fig. 4, p. 202).

The outcrop of the overthrust surface is easily mapped, for the effect of the displacement is, in general, to cause the shales of the lower group to rest on the sandstones of the upper. The overlying displaced rocks have suffered very great mechanical disturbance, as is shown by their high and variable dips and violent contortion, and in some places by brecciation on an extensive scale. The relatively-unmoved strata below are much less disturbed, sometimes not more so than in the north of the island; but along parts of the line they have an altered and steeper dip, and in certain places they are brecciated. The voluminous intrusions of peridotite, gabbro, granite, etc., have given rise to considerable metamorphism of the thermal type, superposed upon the dynamic effects. The results of such metamorphism are more often conspicuous in the displaced strata than in those below the overthrust; but this is only a necessary consequence of the overlying position of the igneous rock-masses. There is no essential connection between the dynamic and the thermal transformations, and the latter seem to stand always in direct relation to the proximity of the large plutonic intrusions. The phenomena of metamorphism of the crush-breccias and numerous other circumstances enable us to affirm that the thermal metamorphism was subsequent to the dynamic, and its distribution warrants us in ascribing it, in the main if not wholly, to the Tertiary intrusions. In making this statement we ought to reserve the case of certain gneissic rocks, found above, and sometimes below, the overthrust surface, which will be discussed farther on.

The belt of displaced rocks will now be considered in more detail, beginning at the centre of the island. To the west the overthrust strata are cut out (as has been remarked) by the igneous intrusions, which in this part assume something of the boss-like habit. The overthrust is first met with a little to the east of the north-and-south valley in which lies Loch Sgathaig or the Long Loch. The main line of the displacement follows here a very sinuous course, though with a general easterly direction, and it is interrupted in

Fig. 3.—*Section from Barkeval Pass (east of Barkeval) to Kinloch Castle, Isle of Rum.*



[Scale : 4 inches = 1 mile.]

Towards Kinloch the relatively-unmoved Torridonian sandstones are seen in their natural position. The heavy broken lines (t^1 and t^2) represent minor and major overthrusts respectively. Above come highly contorted Torridonian shales, succeeded by a crush-breccia of sandstone and shale (Br.). To the left appear the lowest members of the stratiform complex of Tertiary intrusive rocks, namely :—

U = Ultrabasic group, with alternations of more and less felspathic types.

Gb = Gabbro.

F = Porphyritic quartz-felsite.

several places by abruptly-intruded igneous masses. The relations are of a complicated kind, and it appears that more than one overthrust occurs. The displaced strata are mostly shales in a metamorphosed state, and they have high dips, often approaching the vertical, in various directions, but chiefly to north and north-east. The metamorphism is not always of a very advanced grade, the only conspicuous new mineral being brown mica in flakes set parallel to the lamination. The angular granules of quartz, which are abundant in some beds, are quite unaltered [10489, 10490]. Some associated sandstones, evidently metamorphosed, also show the formation of brown mica, the detrital grains of quartz and felspar being unchanged [10488]. In another specimen the alteration is greater, the clastic structure being partly obscured. Here some green hornblende has been produced, and in places granules of a pale augite, apparently along a veinlet which has contained a little calcareous matter [10487]. A crush-breccia, which occurs in a few patches of no great size, has also undergone metamorphism.

The line of the overthrust runs eastward, passing north of Loch Bealach Mhic Neill and Loch Gainmhich, and then turns more to the south-east. All along this line the sandstones below, or to the north of, the main overthrust show no special sign of disturbance, except a change of dip. As we approach from the north, the inclination of the strata becomes steeper, and takes a northerly direction, and as we pass eastward the dip becomes east of north, that is, still away from the overthrust. In Coire Dubh, opening north-eastward towards Kinloch, these highly tilted sandstones are cut off by a subsidiary surface of movement, and below this minor overthrust the beds have the normal inclination (see fig. 3, p. 198).

In that portion of the displaced belt of rocks which we have followed so far, sandstones are seen in several places above the main surface of the movement. They occur always south of the overthrust shales, which they doubtless succeed, though the observed dips show that the actual junction is not a natural one. The small areas of crush-breccia, which have been mentioned, are found in like situations, and it appears that the conjunction of sandstones and shales has favoured the production of the brecciated structure. It has already been remarked that the undisturbed succession shows a certain alternation of shales and sandstones at the boundary between the two groups, and it is to be supposed that the unequal yielding of the two rocks under mechanical forces would conduce to the setting up of brecciation. The conditions were indeed comparable, in many respects, with those which affected the Manx Slates as described by Mr. Lamplugh.[1]

The most considerable mass of crush-breccia in Rum is that which crosses Coire Dubh (fig. 3), and forms much of the slopes of Meall Breac and Cnapan Breaca on the two sides of the corrie. Though

[1] Quart. Journ. Geol. Soc. vol. li (1895) pp. 563–88; & 'The Geology of the Isle of Man' Mem. Geol. Surv. (1903) pp. 55–58.

cut off to the west and south by intrusive rocks, it has a length of a mile and a width varying up to a quarter of a mile. Its actual thickness is not easily estimated, but is probably about 400 or 500 feet. This occurrence was noticed by Sir Archibald Geikie.[1]

A description of this crush-breccia will apply also to the smaller patches mentioned above. It is a rock of striking and characteristic aspect. In most places both sandstone and shale enter into its composition, fragments of grey sandstone being embedded in a darker and nearly black matrix which consists largely of crushed shale. There are, however, fragments of shale also, though they are less abundant, while, on the other hand, the sandstone has contributed in varying amount to the comminuted matrix. The fragments usually range in diameter from 2 or 3 inches downward, though blocks of larger dimensions are also found. The angles are in general more or less rounded, but the sandstone-fragments have not undergone so advanced a degree of attrition here as at Monadh Dubh: a fact attributable perhaps to the interposition of the softer shale. It is noticeable that the sandstone in the breccia is mainly of the fine-grained grey variety found in the passage-beds to which I have alluded, confirming the supposition that the breccia is formed in great part by the breaking up of those beds. Immediately overlain by the massive plutonic rocks of the mountain-tract, and invaded, moreover, by two considerable masses of a peculiar porphyritic felsite, the breccia is in most parts more or less metamorphosed; the sandstone in it being sometimes almost converted into a quartzite, while the shale is much indurated and otherwise altered. It is clear that this metamorphism is posterior to the brecciation, even apart from any evidence as to the Tertiary age of the intrusions. The porphyritic felsite is in some places crowded with fragments picked up from the breccia, and it also encloses a large amount of gabbro-débris in a partly-digested state.

The limestone which was so noteworthy a feature of the Monadh-Dubh breccia is wanting here, nor have I detected fragments of that rock in any of the breccias in this belt of country; but Sir Archibald Geikie noted a patch of limestone in Glen Dibidil.

Following the main surface of overthrust south-eastward from Coire Dubh, we find that a little before reaching Allt Mòr na h-Uamha it is cut out by the encroachment of the gabbro, and is lost for about 900 yards. It reappears at the point where the Dibidil footpath crosses the next burn, Allt na h-Uamha, and is there thrown down a little by a normal fault. Its course is now nearly north and south. The shales above are, as usual, highly inclined and contorted, and they are also indurated owing to the proximity of the gabbro. The sandstones below have only a small thickness, being underlain by the shale-group in its natural position, and the dips are quite normal. Indeed, from here to near Dibidil, a distance of $2\frac{1}{2}$ miles, the strata below the overthrust show, in general, no

[1] 'Ancient Volcanoes of Great Britain' vol. ii (1897) pp. 351, 352.

special signs of disturbance, excepting the contortions on a small scale which seem to affect most of the Torridonian rocks of Rum. The overthrust shales are soon cut out again by the gabbro, and only reappear for a short distance about three-quarters of a mile farther south.

We pass on to Beinn nan Stac, a hill about 1850 feet high, the south-eastern slope of which descends rather sharply to the sea (see fig. 4, p. 202). The average inclination of the overthrust-surface in this place does not differ greatly from that of the ground, so that the displaced shales make a considerable spread on the slope. They may be regarded as of the nature of an outlier, this relation being obscured, however, by the subsequently-intruded gabbro and felsite to the north-west. The shales are highly inclined, often vertical, and their strike varies rapidly from point to point. They are also violently contorted on a small scale, and indurated in consequence of metamorphism. Fine grey sandstone, for the most part thoroughly brecciated, forms the actual summit of the hill, this mode of crushing having been especially operative, as usual, at the passage from shale to sandstone. Nearly along this zone of weakness has been intruded a sheet-like mass of porphyritic felsite similar to that of Meall Breac, and here, too, it has in many places enclosed fragments of sandstone from the crush-breccia. The shales themselves are brecciated in some places, but not on an extensive scale. The relatively-unmoved sandstones below the overthrust are more disturbed on Beinn nan Stac than elsewhere along the line that we have followed, and immediately below the main surface of displacement they show high and reversed dips.

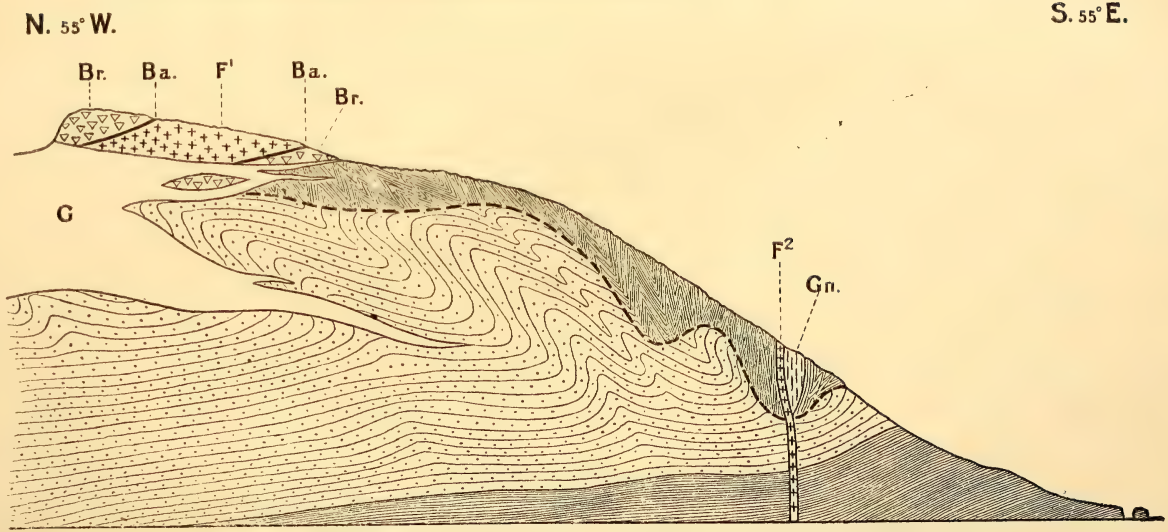
The overthrust outlier of Beinn nan Stac, with much reduced width, comes down to the sea a little east of the outlet of the Dibidil River. Beyond this the strata beneath the overthrust show much more evident disturbance than heretofore, the sandstones being extensively brecciated. There is in places considerable metamorphism, which is here connected with the occurrence of several patches and lenticles of gneiss. Highly-disturbed Torridonian rocks extend up to a rather high altitude on the east side of Sgùrr nan Gillean, and run along the coast for some distance towards Papadil; but our detailed survey has not yet covered the actual termination of the belt of displacement in this direction.

IV. The Geological Relations of the Gneisses.

I have next to notice what is, in some respects, the most interesting feature of the tract under consideration, namely, the occurrence of gneissic rocks at numerous places along the border of the mountains, usually in immediate association with the highly-disturbed Torridonian strata.

The individual occurrences are never of large dimensions, the length being usually less than a quarter of a mile, and sometimes as little as 100 yards. Where the natural boundary is clearly shown, it approximates more or less closely to a lenticular form,

Fig. 4.—*Section through Beinn nan Stac to the coast of Stac nam Faoileann, Isle of Rum.*



[The line of section is indicated on the map, Pl. XIV. Scale : 6 inches = 1 mile.]

The heavy broken line represents the warped surface of overthrusting. Below this the Torridonian shales and sandstones occur in their natural position. Above, the shales are violently contorted and the sandstones brecciated (Br). A lenticle of gneiss (Gn) is shown among the contorted and metamorphosed shales in the lower part of the slope. The other rocks represent normal igneous intrusions of the Tertiary suite, namely :—

G = Gabbro. F^1 & F^2 = Porphyritic quartz-felsite. Ba = Basalt-sheets intruded along the border of the felsite.

The laccolitic mass of felsite (F^1) is not cut off by the gabbro, but is of later date, intruded along the zone of brecciation and stopped by the more massive gabbro.

with its greatest extension conforming with the local strike of the disturbed strata in its vicinity. A number of detached and partly-detached areas of gneiss occur in the central part of Rum, near the western termination of the overthrust belt, the bare white outcrops about Priomh-loch being very conspicuous at a distance. This is a good district for studying the petrography of the rocks, but not their relation to the Torridonian, the map being complicated by irregular intrusions of peridotite, gabbro, and granite. Following the disturbed belt from Loch Bealach Mhic Neill eastward and southward, no gneiss is seen for a long distance, except a small strip, in contact with Torridon Sandstone, involved in the porphyritic felsite on the hill east of Loch Gainmhich. Next, a lenticular mass of gneiss occurs among the altered shales just above the overthrust surface on the lower slope of Beinn nan Stac (fig. 4, p. 202). A strip runs for nearly 400 yards along the Dibidil River, from the ford to the coast, and there are several other occurrences to the west and south-west. It is only in this district, where the strata overridden by the great displacement are unusually disturbed, that gneissic rocks are found below the main overthrust. In addition to these occurrences, all more or less closely bound up with the displaced Torridonian strata, gneisses are found about Loch Sgathaig bounded only by granite, gabbro, and picrite; while, farther west, an isolated patch a quarter of a mile long occurs in the interior of the main granite-area, forming the summit of Beinn a' Bhàrr-shaibh, to the east of Orval.

These rocks, with well-marked parallel banding and foliation, and frequent alternations of different lithological types, are perfectly characteristic gneisses in the ordinary descriptive sense of the word. Indeed, their appearance led Sir Archibald Geikie to assign them to an Archæan age.[1] Closer examination, however, compels me to dismiss decisively the hypothesis that these rocks are portions of a pre-Torridonian formation brought up by overthrusting. The gneisses are clearly intrusive in the Torridonian strata. Not only do they penetrate these in an intimate manner, but they sometimes enclose fragments of them in a highly metamorphosed state. Thermal metamorphism, as I have remarked, has affected in varying degree a large portion of the disturbed strata along the mountain-border, and I have ascribed it in general to the intrusion of the gabbro and other plutonic rocks of Tertiary age; but the highest grade of metamorphism is found in the rocks bordering the relatively-small intrusions of gneiss. On the lower slope of Beinn nan Stac, for example, for a considerable distance from the lenticle of gneiss, the contorted shales are converted into a hard black, almost flinty rock, resembling a compact basalt. Elsewhere sandstone has been transformed into quartzite.

We have, then, full assurance that the gneisses are younger than

[1] 'That some of these rocks are portions of the Lewisian Series can hardly be doubted, and their structure and relations are probably repetitions of those between the Lewisian gneiss and Torridon Sandstone of Sleat in Skye,' Ancient Volcanoes of Great Britain, vol. ii (1897) p. 351.

the Torridonian strata with which they are in most cases associated. It remains to enquire their relation to the next marked epoch in the geological history of Rum, namely, that of the overthrusting, which we may safely correlate with the great Palæozoic crust-movements in other parts of the Scottish Highlands. In no case is there anything to indicate that the gneisses themselves have been moved. The boundaries of the lenticular masses, which on that supposition would be favourable places for shearing and faulting movements, seem to be in fact, so far as they are exposed, normal igneous junctions. The lenticular form and the general parallelism with the local strike are features common in ordinary laccolitic intrusions, and due to the natural tendency of an intruded magma to follow the direction of least resistance. Moreover, this parallelism does not extend to the gneissic banding, which is certainly of the nature of a primary flow-structure. With rare exceptions, the gneisses show no sign of crushing, brecciation, or internal fracture of any kind. Some of the occurrences are in the immediate neighbourhood of, or even in contact with, crush-breccias; but the gneisses have not contributed to the composition of these breccias, a fact inexplicable if the crushing be supposed posterior to the intrusion of the gneiss. The Dibidil district does, indeed, afford a certain exception to this generalization, for there brecciated gneiss is seen in one or two places. Such occasional phenomena do not, however, invalidate the argument; for, apart from all consideration of these gneissic rocks, it is probable that, here as elsewhere, there was in Tertiary times a renewal of mechanical disturbance along the old lines, though with much less intensity. Brecciation and other effects of crushing are found on a much more extensive scale than at Dibidil in undoubted Tertiary granites and gabbros in some parts of Skye. The observations which have been adduced warrant us then in believing that the gneissic rocks of Rum were intruded at some time posterior to the great crust-movement of the region. This conclusion still leaves two alternatives open : the intrusion of the gneisses may conceivably have followed the overthrusting after no long interval, being a later incident of the same great system of disturbances, or it may be referable to a distinct and long posterior epoch. The only later igneous intrusions known to have affected this part of Scotland are those of the Tertiary suite, and the question of the date of the Rum gneisses turns, therefore, upon the relations of these rocks to those of admitted Tertiary age, which are abundantly represented in the same tract. We shall see that the observed relations afford somewhat strong ground for believing that the gneisses are of late geological date, and are merely special phases of the plutonic intrusions of the mountains.

The rocks building the large intrusive bodies fall into three principal groups, which succeeded one another in order of decreasing basicity: (i) the ultrabasic group, comprising peridotites, olivine-anorthite-rocks, enstatite-anorthite-rocks, and many other varieties; (ii) gabbros; (iii) granites, including granophyres. In

addition to these plutonic rocks, there is the peculiar porphyritic quartz-felsite already mentioned, of somewhat later date, confined to the overthrust belt and generally intruded among or in contact with the crush-breccias. Since the prevalent rock among the gneisses is always of acid composition, it is with the third group, if any, that we must correlate it. The rocks which we have mapped as gneiss and granite, respectively, come together in the central part of the island, about Loch Sgathaig. The ground here is much obscured by peat, and the boundaries laid down are merely empirical, being drawn to divide as simply as possible the outcrops which show gneissic banding from those which do not. There is nothing inconsistent with the supposition that the two are parts of one and the same mass, but the exposures are not sufficient to warrant a conclusion either in that sense or the opposite. Farther west, on Beinn a' Bhàrr-shaibh, the evidence is much clearer. Here a patch of well-characterized gneiss, mainly of granitic composition, but with some basic material, forms the summit of the hill, and extends for some distance down the south-eastern slope, and, as stated above, this patch is wholly surrounded by granite. On the bare upper part of the hill the relations between the two rocks are easily examined, and it is seen that no sharp divisional line can be drawn between them. The one appears to graduate into the other, often through a transitional zone of a rather coarse-looking or pegmatoid rock, a type common in other localities as an integral part of the banded gneissic complex. Thus, at the only place where the relations are clearly displayed, the gneiss is to all appearance inseparable from the granite. The locality and the situation of the patch of gneiss on the shoulder of the hill are consistent with the supposition that the original boundary of the large acid intrusion was not far above this place. The porphyritic quartz-felsite of the mountain-border belongs to a later phase of Tertiary igneous activity, and its posteriority to the gneiss is easily demonstrated. On the hill east of Loch Gainmhich, a strip of gneiss nearly 100 yards long, with metamorphosed Torridon Sandstone adherent on one side, is enveloped in the felsite. The lower intrusion of felsite on Beinn nan Stac (fig. 4, p. 202) seems to be of dyke-like habit, forced in along the border of the lenticle of gneiss.

The relation of the gneiss to the ultrabasic and basic intrusions is yet to be considered. It is to this that we should look for a final test of the suggested Tertiary age of the gneissic rocks; for, on this hypothesis, the gneiss, or at least the acid rock which is its dominant element, should be newer than the massive intrusions. In the central part of Rum, near Loch Sgathaig and Priomh-loch, the gneiss is bounded in several places by peridotite and gabbro; and one patch, west of Priomh-loch Mòr, is entirely surrounded by those rocks. I have not, however, detected here any exposure of the actual junction, from which one might draw conclusions. The gneiss in this district has a high dip to the north, irrespective of the form of its boundary; but this does not imply that the gneissic

banding is truncated by later intrusions, for the same thing is seen in other places where the gneiss is in contact with sandstones or shales. Gneissic banding and foliation, though of the nature of fluxion-structures, are not necessarily parallel to the boundaries of the mass.

From the Dibidil district we obtain evidence of a more positive nature. Here the main body of gabbro has retired somewhat inland; but, as elsewhere, there are numerous small intrusions of that rock in the country fringing the mountains. These intrusions take the form of lenticles and dyke-like strips, some of which are closely associated with the gneiss, in several places forming an inconstant border to it. The strip of gneiss which occupies the lower part of the Dibidil River is partly bordered by gabbro on both sides, and again at its southerly termination. The relation suggested is that the gneiss has been intruded along the side of, and partly through, the gabbro, just as granites have been intruded beside and partly into gabbros at many other places in the Inner Hebrides. Where the junction is clearly exposed, direct proof of this sequence of intrusions is found. At a place on the left bank of the river, a little way below the ford, the gabbro is seen to be penetrated by tongues of gneiss running out from the main body, as well as by narrower reticulating veins consisting chiefly of the pegmatoid rock which here, as elsewhere, is a component element of the gneiss. At the same place, detached blocks of unmistakable gabbro are enveloped in the gneiss itself. This gneiss is quite typical, and the gabbro is indistinguishable from that of other intrusions in the district. Here, then, we seem to have ocular proof of the conclusion, already foreshadowed by other considerations, that the gneissic rocks of Rum belong to the great Tertiary suite of eruptions. The only alternative, with the evidence before us, is to assume the existence of an older group of gabbros identical in appearance with the Tertiary gabbro in the immediate vicinity—an artificial hypothesis not supported by any known facts.

Another enquiry, not yet touched, relates to the very significant distribution of the gneissic intrusions. The fact that all the occurrences noted are associated with the highly-disturbed belt of country suggests some connection between the gneissic structure and the crust-movements; of course, those of Tertiary date, which recurred, as has been noted, in places already affected by the much more intense Palæozoic disturbances. A like conclusion is enforced by an examination of the strike of the gneissic banding and foliation, which is not concordant with the boundaries of the several intrusive bodies, but seems to obey some larger law. The dips, almost always at high angles, are northerly in the central part of the island, inclining rather towards north-north-east on Beinn a' Bhàrr-shaibh. In the small intrusion of gneiss on the lower slope of Beinn nan Stac the dip is west-south-westerly. Rapid changes of strike and dip are found only in the Dibidil neighbourhood, where the older system of crust-movements had been especially vigorous,

and where, too, disturbance posterior to the intrusion of the gneiss was sufficiently intense to produce noteworthy brecciation in that rock. It may be plausibly conjectured that the movements of which this last effect is the witness were initiated somewhat earlier, and that the fluxion in the gneiss itself is related to it.

V. The Composition and Origin of the Gneisses.

I have now to discuss the petrographical characters of the gneissic rocks of Rum. In doing so, I shall adopt the conclusion to which the field-evidence has led me, and treat the gneisses as a special facies of the Tertiary plutonic rocks of the region. It will be seen that this position is strengthened by many peculiarities of the gneissic rocks themselves, to be noticed below. One explanatory remark is called for at the outset. Considered simply as intrusions, the gneisses are to be correlated, as we have seen, with the granites, but, having regard to their actual materials, the granite-magma has supplied only one element, though the dominant one, of the gneissic complex. The basic and ultrabasic rocks have contributed in a minor degree, and so also to some extent have the Torridonian sediments. These various subsidiary components are for the most part much disguised, and have often quite lost their individuality in the resulting complex, for the acid magma by which they have been enveloped and impregnated has not only metamorphosed, but often partly or wholly digested them. In a word, much of the gneiss is a hybrid rock, and this composite origin frequently betrays itself in unusual mineral associations. Since the effect of my study of the rocks is to connect the gneisses, on petrographical as well as on geological grounds, with the Tertiary suite of intrusions, we will first glance at the occurrence of gneissic structures in rocks admittedly of Tertiary age in the same petrographical province.

Nine years ago, Sir Archibald Geikie & Mr. Teall[1] described the highly developed gneissic banding in the Tertiary gabbros of Druim an Eidhne, in Skye, and pointed out the instructive bearing of the phenomena described upon the origin of such gneisses as those of the Lewisian Series. The present writer has found that such banding affects in varying degree a considerable portion of the gabbros of both Skye and Rum, while it is much more prevalent, and attains a more striking development, in the more variable group of ultrabasic plutonic rocks in the same islands. The authors cited proved clearly that (at the locality described by them) the banding has resulted from the intrusion of a heterogeneous magma, which was drawn out into parallel streaks by flowing movement without any effective intermingling of the different portions. Such is undoubtedly the explanation of the

[1] Quart. Journ. Geol. Soc. vol. l (1894) pp. 645–59 & pls. xxvi–xxviii.

detailed structures in all these banded rocks, though the larger alternations seem rather to represent distinct and successive intrusions, with a stratiform disposition following the same direction. We may infer that the rarity of banding in the granites and granophyres of the same districts is connected with the greater homogeneity of the magmas from which these rocks have been formed, and a study of the several groups amply confirms this conclusion. Throughout the Inner Hebrides—not to go farther afield—the acid plutonic rocks are much more uniform, on a small as well as on a large scale, than the basic, just as these latter rarely approximate to the extreme variability of the ultrabasic.

At certain places in Skye, however, the acid intrusions assume locally a strongly gneissic structure, and the circumstances of these exceptional occurrences are very significant. They may be examined at more than one locality on Marsco, where considerable bodies of gabbro have been enveloped in, and attacked by, the granite-magma. The acid rock in these places is modified by the inclusion of a certain amount of gabbro-débris, which is found in various stages of digestion down to complete absorption, and the banded rocks form offshoots from the main body traversing the altered gabbro-mass. They compare closely with some of the more acid portions of the Rum gneisses, and are also, like these, intimately bound up with a purer pegmatoid rock, which suggests an effort of the acid magma to free itself from foreign contamination. These exceptional occurrences, in places where the relationships of the rocks are unequivocal, are especially instructive from the point of view to which we have been led. Primary gneissic banding in an igneous rock may be regarded as the result of flowing-movement in a heterogeneous magma. In these stratiform intrusions we may reasonably postulate a considerable degree of flow in acid and basic magmas alike, and the development of any pronounced banding will thus depend upon the greater or less heterogeneity of the magma. But heterogeneity may arise in two ways, illustrated on the one hand by the gabbros of Druim an Eidhne and the peridotites of Allival, on the other by the veins on Marsco and the Rum gneisses. The requisite variability must be attributed in the former case to imperfect segregation of the differentiates from one parent magma, and in the latter case to imperfect commingling of distinct rocks (including rock-magmas), the presumable consanguinity of which is of a more remote degree. In a due recognition of this principle is contained the clue to the peculiarities presented by the gneissic rocks under discussion.

I proceed to consider, though without going deeply into petrographical details, the characters of the gneisses themselves. Most of them are more or less markedly-acid rocks, of dominant quartzofelspathic composition; but of these prevalent acid rocks only a part are of a pure type, representing an unmixed granite-magma. This type is found, associated with other types, basic and hybrid, in all the localities mentioned, though it does not constitute the

principal portion of the exposures. Good examples may be examined in the neighbourhood of Priomh-loch Mòr and Loch Sgathaig, and by the roadside north of the latter. These rocks are in themselves devoid of any banded structure, although in their mode of association with other types in the complex they conform with the common parallel disposition. Apart from their mode of occurrence, there is nothing in their appearance to distinguish them from the ordinary granitic rocks of the island and of other islands in the Inner Hebrides. Their essential identity with these is borne out by a microscopic examination. There is a strong tendency to delicate micrographic intergrowths of felspar and quartz, imparting to the rocks the microstructure which is implied in the name 'granophyre,' as used by Rosenbusch. This is the most marked characteristic of the acid plutonic rocks of Tertiary age throughout the British area, the rocks of which I have spoken as granites, although I might with equal propriety follow Sir Archibald Geikie in applying to them as a group the name 'granophyre.' A rock of the type that we are considering has acid felspars and quartz as its chief minerals, and consists principally of micropegmatite. A certain portion of the felspar, and more rarely of the quartz, may form more or less distinct crystals, but the micropegmatite encroaches upon the borders, or even affects the interior, of the crystals. The felspars are orthoclase and oligoclase, of which the former builds the more regular and delicate intergrowths with quartz, while the latter more frequently builds distinct crystals. The ferromagnesian element is sometimes hornblende, sometimes biotite, while magnetite and apatite are found as minor accessory minerals. This description applies equally to the purely-acid portions of the gneissic complex, and to the prevalent type of the large granitic tract of Orval and the neighbouring hills. A medium texture prevails, but some of the rocks have rather a coarse-grained pegmatoid appearance in the field. These latter occur as strings or veins in the complex, and on Beinn a' Bhàrr-shaibh are interposed as a border between the gneissic and non-gneissic rocks.

The pure granophyric type graduates into another, which is still of thoroughly acid composition, but shows peculiarities which point to the intervention of some element of alien origin. Thus, from the little roadside-section near Loch Sgathaig comes a biotite-bearing granophyre [10492] answering to the above description, while close by, and inseparable from it, occurs a rock of precisely the same character, except that, in addition to the flakes of biotite, it contains very numerous little crystal-grains of hypersthene [10493]. The occurrence of a mineral so little expected in a granophyre is significant, and the explanation is not far to seek. It is found in the presence, in the immediate neighbourhood, of abundant inclusions or xenoliths of a dark close-grained rock, evidently of basic composition; and other specimens selected at this place demonstrate very clearly the origin of the pyroxene-grains by reaction between the basalt and the acid magma. These specimens have no marked gneissic banding, and they illustrate in a very instructive way

circumstances which in many other localities have been obscured by a more noteworthy amount of flowing-movement.

It may be remarked here, parenthetically, that the inclusion and partial or complete destruction of basic rock-débris by an acid magma, which will be seen to be so important a factor in the production of the gneisses of Rum, is entirely in accord with our reference of these rocks to the same great suite as the larger bodies which form the principal hills of the island. Nothing is more characteristic of the Tertiary intrusions of Britain as a whole than the frequent intimate association of widely diverse rock-types, often giving rise by admixture to rocks of very peculiar kinds. Sometimes angular fragments of a rock have become involved in a newer magma and entered into reactions with it; sometimes the earlier rock has been invaded before it was cooled, or even before it was completely solid, by the later and different magma; sometimes, again, the imperfect admixture has been effected in some intratelluric reservoir prior to intrusion. The intensity of the mutual reactions has been controlled by the temperature and other physical conditions implied in these different circumstances; but it has also depended upon the degree of difference between the two rocks involved, the maximum effects being found where a basic rock has been attacked by an acid magma. There has thus resulted, in different cases, a rock with evident xenoliths, more or less altered, a hybrid product with scattered xenocrysts, usually much disguised, or, in the extreme case, a rock which shows in a given specimen no direct indication of any foreign element. Even this last, however, will often betray its origin by something unusual in its mineralogical constitution.[1] Good examples of these various phenomena may be studied without going beyond the Isle of Rum. I need cite only one instance, that of the eastern border of the principal granite-tract, where it is conterminous with part of the large area of ultrabasic rocks. There is a zone of evident admixture, which in places attains a width of about 50 yards. Where this well-marked zone, with the appearance of a breccia, is wanting or much reduced, it is because mutual reactions of a more advanced kind have resulted in complete dissolution of the peridotite-xenoliths in the acid magma. The evidence of this is seen in little clots or patches rich in ferromagnesian silicates (often including hypersthene) scattered through the granite or granophyre to some distance from the line of contact. The final breaking-up of these has doubtless been facilitated by a certain amount of differential movement in the magma.

Effects of the same general kind as those just noticed, but with great variety in detail, have been studied by the present writer in many of the Tertiary intrusions of Skye; and a comparison of the phenomena with those of the Rum gneisses leaves no doubt that a

[1] On this point, see 'Igneous Rock-Series & Mixed Igneous Rocks' Journ. of Geol. [Chicago] vol. viii (1900) pp. 389-99. I have described numerous occurrences of xenolithic and hybrid rocks, with some discussion of the general questions involved, in a forthcoming memoir of the Geological Survey on 'The Tertiary Igneous Rocks of Skye.'

great part of the latter are susceptible of explanation on these lines. A minute description of the rocks would be merely an expansion of this general statement, and for our immediate purpose a few brief remarks will suffice.

Where recognizable xenoliths occur in rocks forming part of the gneissic complex, they are, if not in course of dissolution, at least highly metamorphosed, and their original nature is not always patent to observation. In some cases they are of a compact black rock, which looks like an indurated shale, and in thin slices shows a laminated structure marked by abundant brown mica and granular magnetite. There are, however, none of the special aluminous minerals, such as sillimanite, which usually characterize highly-metamorphosed argillaceous sediments, and the presence of porphyritic felspars is proof of an igneous origin. The majority of the xenoliths clearly come from ultrabasic and basic igneous rocks, though often apparently of finer texture than the common peridotites and gabbros of the island. They usually illustrate an advanced stage of replacement, a term which I use to denote the transformations consequent upon interchange of substance with the enveloping acid medium. It is a common observation in other districts examined by me that such replacement may proceed almost without limit while the sharp boundary of the original enclosed fragment remains intact, and of this the Rum gneisses afford abundant illustration. The xenolith thus comes to be replaced by a cast or pseudomorph, preserving the former outline but consisting of a granular aggregate wholly of new formation, to which the acid magma has contributed. Granules of pyroxene are the principal elements of the replaced xenoliths. They are partly of augite, but more commonly of hypersthene, a mineral which might confidently be expected from the reaction of olivine with a magma rich in silica. The reciprocal modification of the acid matrix, essentially an enrichment in the dioxide-bases, shows itself in a somewhat diminished proportion of quartz and an increased prominence of the ferromagnesian silicates, lime-bearing felspars, and magnetite. Pyroxene-granules are often abundant, but these are in great part mechanically detached from the borders of the transformed xenoliths. The micrographic structures, which rule in the purely-acid portion of the complex, are usually lost in these partly-basified products, a feature constantly observed in similar xenolithic and hybrid rocks in Skye.

Rocks of the general type described, sometimes graduating into pure granophyres, show little or no gneissic banding; and in the well-banded gneisses, which make up the principal part of the complex, xenoliths have usually been obliterated. This is easily understood. We have seen how the enclosed fragments are transformed to mere aggregates of granules, and it is evident that the preservation of their original outlines is contingent on a condition of tranquillity in the surrounding magma. Movement would quickly resolve the aggregates into detached granules, and indeed the thin slices enable us to verify this breaking-down process in various stages. Where strong fluxion has supervened, as is the case

in most parts of the complex, the process has, of course, gone much farther. Thus the flowing-movement, while bringing out more prominently the heterogenous composition of the rock-body, has effaced the evidence as to how the heterogeneity arose. The missing links are supplied by a comparative study of different localities. Given a granitic magma enclosing débris of more basic rocks, an irregular distribution of the débris such as is seen where the xenoliths are still traceable, reactions between the basic rocks and the acid magma of a kind familiar in many other districts, and that drawing-out of the whole by flowing-movement which is proved by the banded structure, we have a complete explanation of the principal part of the Rum gneisses.

There remain certain thoroughly-basic rocks which form bands in some parts of the complex, but make up only a small fraction of the whole. These illustrate another principle elsewhere abundantly exemplified in the British Tertiary suite, namely, the tendency of an acid intrusion to follow closely the line of an earlier basic intrusion, often accompanied by noteworthy reactions between the two rocks. I have not thus far expressed any explicit opinion as regards the source of the ultrabasic and basic xenoliths discussed above. It is possible that they were in part brought up by the acid intrusion, having been derived from underlying rock-masses; but of such concealed masses we have no other clear indication, the known intrusions of gabbro, peridotite, etc., being situated at higher horizons. We may perhaps suppose with more probability that the xenoliths are relics of ultrabasic and basic intrusions which occupied in part the present position of the gneiss, prior to the more voluminous intrusion of acid magma which destroyed them. This hypothesis has the advantage of accounting at the same time for the continuous or lenticular bands of basic rocks which are in places associated with the more acid and hybrid rocks as integral parts of the complex.

These basic rocks appear to have been of the nature of gabbros, now transformed by metamorphism, and in some measure by interchange of material with the acid magma. A dark hornblendic rock of this kind, with more or less evident banding and foliation, is a prominent part of the gneissic complex at a locality north-east of Priomh-loch Mòr. It has the general aspect of a medium-grained diorite [10733]. In a thin slice it is seen that the deep green hornblende, which makes up more than half of the rock, presents in places the crystal-outline proper to that mineral, proving that it is not merely pseudomorphic but has crystallized as such. The rest of the rock consists chiefly of a finely-striated plagioclase ; but there is also some unstriated felspar, which may be orthoclase, and a few little interstitial grains of quartz are seen. These last two minerals probably point to a certain impregnation of the recrystallized basic rock by the granitic magma.

For comparison I take another example from the small patch of gneiss enclosed in the porphyritic quartz-felsite of the hill east of

Loch Gainmhich. The basic rock here forms a mere seam a few inches thick, and has presumably been more vulnerable to the invading acid magma. It is of rather coarse texture, and has a pronounced fissile structure, due to the parallel disposition of the crystals of hornblende, which is again the chief constituent [10495]. These crystals, ranging up to a quarter of an inch in length, are of ragged shape and of green colour. Orthoclase becomes here a more abundant element, while the accompanying striated felspar seems to be an oligoclase. Some quartz occurs, but only in the interior of the hornblende, where also strings of magnetite-granules and a little brown mica seem to have resulted from a certain corrosive action.

It is doubtful whether the sedimentary rocks have contributed in any sensible degree to the composition of the gneisses. At a junction of gneiss with pebbly grits to the east of Priomh-loch Mòr there is evidence of a certain amount of incorporation of the latter rock in the former, pebbles of quartz being recognizable in the gneiss for a short distance from the actual contact. The felspathic sandstone, which is the common type in the Torridonian, would probably be more easily attacked than a purely quartzose rock, and there is evidence at several localities in Rum that the sandstone has been partly fused in contact with an intrusion. Mr. Clough has noticed a like effect on the edge of peridotite-intrusions on the Isle of Soay, where a certain mingling of the fused sandstone with the ultrabasic magma can be verified. All my observations go to show, however, that any such action is of exceedingly limited extent. Again, at certain junctions of the gneisses with Torridonian shales it may be seen that the igneous magma has penetrated in thin leaves for a short distance along the laminæ of the shale, the latter being highly metamorphosed. I have found nothing to suggest that these local effects have any significance in respect of the origin of the gneissic rocks. It is at least certain that merely metamorphosed sediments form no part of the complex, which consists wholly of rocks crystallized from igneous fusion.

VI. Summary of Conclusions.

In conclusion I will indicate summarily the chief results to be deduced from the observations recorded above. It has been shown, firstly, that the highly-disturbed region of the North-Western Highlands, extending into the south-eastern part of Skye, is further prolonged into the Isle of Rum, where a belt of overthrust strata borders the principal high ground. It is perhaps not impossible that the main surface of movement here corresponds with the great 'Moine Thrust,' which Mr. Clough has traced through the Sleat district of Skye to within about 10 miles of our ground. It is, however, more probable that we have to do here with one of the less extensive displacements beneath, and in advance of, the great one. Its only effect, tectonically, in the mountain-border is to

cause lower parts of the Torridonian to rest on higher parts of the same series. On a smaller scale, too, the mechanical re-arrangement of the rock-masses affected is not of the most extreme type, being limited in general to contortion and brecciation. The mechanical conditions controlling these several processes form a subject of enquiry outside the scope of the present communication. I have, however, pointed out that the Torridonian strata forming the northern half of Rum, which I regard as, in a general sense, in their natural position, evince nevertheless abundant indications of disturbance on a small scale; and from this we may not improbably infer the existence of an important surface of displacement at no great distance above the present surface of the ground.

This inference is in some measure strengthened by the occurrence of an isolated patch of overthrust and highly disturbed rocks on Monadh Dubh, in the north-western part of the island. We cannot, however, assume that the surface of displacement in this place is identical with that of the mountain-border. Both the tectonic arrangement and the induced rock-structures seem to point to a higher order of disturbance; for the Cambrian limestones have here been involved with the Torridonian rocks, and, in addition to brecciation of a more advanced type than before, there has been a shearing of the sandstone to produce a schist or mylonite. The actual disposition of the rocks, as described above, has suggested that the overthrust seen on Monadh Dubh may be subordinate to one of more imposing magnitude at a somewhat higher horizon.

In Rum, as in Skye, the mapping proves that the 'thrust-planes' have in some places been bent into bold curves; and this folding is most probably referable, at least in great part, to a Tertiary epoch. It is certain that in both islands there was a belated and relatively feeble revival of crust-movements at a late date; and, though we cannot point to Tertiary overthrusts, we find locally evidence of considerable brecciation and comminution of rock-masses at a time posterior to the great plutonic intrusions. In this way must be explained the local brecciation of the gneiss near Dibidil.

The second principal object of the present communication is to draw attention to a group of igneous gneisses in the central and south-eastern districts of Rum, to establish their Tertiary age, and to point out how the strong gneissic banding which they so frequently display has originated. As regards the question of age, we have seen that the rocks are intrusive in the disturbed Torridonian strata, that they are newer than the great system of crust-movements, and that they are found to send veins into the Tertiary gabbro. The evidence upon which this last statement rests has been observed only at a single locality, but it does not seem seriously open to question. There is further the consideration that where the gneiss is contiguous with the ordinary granite (or granophyre) of the western district, there appears to be a passage from the one rock into the other. Petrographically the purely-acid portion of the gneissic complex, which itself is not banded, is identical with the prevalent type of the admittedly-Tertiary acid intrusions; while

the other elements which enter into the complex may be interpreted as representing other known members of the Tertiary suite, disguised by the metamorphosing and corroding action of the acid magma, fused by it, and forming with it various xenolithic and hybrid rocks.

In their paper on the banded gabbros of Skye, Sir Archibald Geikie & Mr. Teall, after demonstrating the origin of the gneissic structure there by fluxion in a heterogeneous rock-magma, urged the application of the same principle to some gneissic rocks of much greater antiquity. The facts now recorded suggest a certain extension of the idea there thrown out. It appears that the requisite heterogeneity, which in some cases arises from imperfect differentiation, may in other cases be brought about by admixture; and that there may be produced in this way banded rocks which, although of purely igneous origin, present unusual mineralogical associations, and do not readily find a place in any systematic scheme of normal igneous rocks. Whether this principle also may have an application beyond the particular case described above is a question which I shall not presume to decide.

EXPLANATION OF PLATE XIV.

Geological sketch-map of the Isle of Rum, reduced from the field-maps to a scale of 1 inch to the mile. In order to avoid needless complication the inland lochs and streams are omitted, as well as the less important hills; also all geological details not relevant to the subject of the paper; in particular, the very numerous small plutonic intrusions, dykes, and sheets of Tertiary age.

The area not yet surveyed, in the south and south-west of the island, is occupied wholly by Tertiary igneous rocks, excepting only the southern termination of the disturbed Torridonian belt.

Discussion.

Prof. Judd congratulated the Author on the splendid work which he had been doing in the Inner Hebrides, and especially in the little-known island of Rum. He had himself confined his necessarily rapid traverse of that island (nearly thirty years ago) to the great igneous masses, and had paid little attention to the Torridonian rocks, but the account given by the Author of the disturbances undergone by these ancient rocks, as well as of gneissic structures formed in igneous masses near their planes of junction, was of a most interesting and suggestive character.

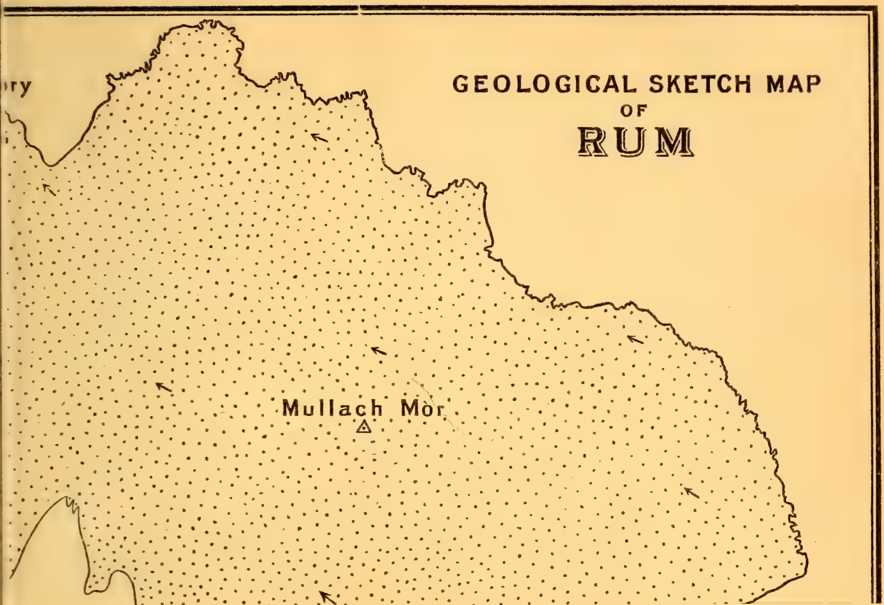
Prof. Bonney said that he was not likely to differ from the Author's interpretation of the gneisses, because he had already, on more than one occasion, called attention to the formation of banded gneisses and hornblende-schists by the intrusion of an acid into basic rocks, as in Cornwall and Sark. He thought that sometimes there was, though not very commonly, local melting of a more basic and solid by a more acid and liquid material, and sometimes a large mass at a very high temperature broke into and mixed with other large masses, which also were extremely hot and perhaps not

completely solidified; so the two were drawn out together, as in the common experiment of making a colour-banded glass.

The President, after referring to the great theoretical interest of the paper and to its richness in detailed observations, enquired whether the direction of overthrusting in Rum (which, to judge from the sections, appeared to have been towards the south-east, and consequently different from that in the North-Western Highlands generally) was a local phenomenon only, or was more or less regional. He gathered that the Author practically accepted the view that the origin of the gneissose banding, and its attendant phenomena, was due to the injection and consolidation of a heterogeneous magma during crust-movement. Referring to some observations of his own, made during a visit to Norway in 1890, he had himself been led to the opinion that, in some instances at least, the phenomena might be owing to the differentiation of a single original magma cooling in more or less laccolitic conditions under a creeping but irregularly-moving rock-cover. The parts of the collective mass might present all varieties of structure, differentiation, and injection—from those in which the material remained practically homogeneous, through stratiform stages and areas of more or less differentiated material where affected most by the crust-movements, to the final stages where the whole, practically cooled, mass became fissured and injected by material, in part segregated, and in part derived from greater and still unconsolidated depths below. A fine example is cut through in the roadside cliffs at Vik, at the head of the Hardanger Fiord, which would well repay a detailed study.

The Author thanked the speakers for their remarks. With reference to Prof. Bonney's observations, more especially concerning the banded rocks of the Cornish coast, he (the speaker) had understood that the structures there were attributed in the main to the deformation of solid rock-masses. He fully agreed with Prof. Bonney in holding that the dissolution and absorption of an earlier igneous rock by a later igneous magma had often been facilitated by the circumstance that the former was still hot, or even not wholly consolidated, when invaded by the latter.

In reply to the President, he said that, in Rum as in Sutherland, the direction of the Mid-Palæozoic crust-movements was from south-east to north-west. The much feebler Tertiary disturbances were indicated by brecciation, and probably by folding, but he was not able to decide from which quarter the thrust at that epoch was directed.


GEOLOGICAL SKETCH MAP
OF
RUM
Mullach Mor
ry


GEOLOGICAL SKETCH MAP OF RUM
N
Kilmory
Section through Monadh Dubh
Sgaorishal
Mullach Mòr
Guirdil
Kinloch
Orval
Barkeval
Alliyal
Askival
Ashval
Harris
Sgùrr nan Gillean
Dibidil
Section through Beinnan Stac
Papadil
EXPLANATION
TORRIDONIAN SANDSTONES
TORRIDONIAN SHALES
CRUSH-BRECCIAS
MYLONITE
GNEISSIC ROCKS
BASALTS, ETC.
ULTRABASIC GROUP
GABBRO
GRANITE
PORPHYRITIC-QUARTZ-FELSITE
TERTIARY
DIPS
NORMAL FAULTS
OVERTHRUST FAULTS
SCALE OF MILES
0
1
2
3

18. *On the* Occurrence *of* *Dictyozamites* *in* England, *with* Remarks *on* European *and* Eastern Mesozoic Floras.

By Albert Charles Seward, Esq., M.A., F.R.S., F.L.S., F.G.S., Fellow of Emmanuel College, Cambridge. (Read February 25th, 1903.)

[Plate XV.]

Among several species of Inferior-Oolite plants recently collected by the Rev. John Hawell, M.A., F.G.S., and sent to me for examination, I found a few fragments of *Dictyozamites*, a genus of especial interest from the point of view of the geographical distribution of Mesozoic plants. Mr. Hawell obtained the plants from a bed of ironstone on the northern face of the Upleatham outlier, near Marske-by-the-Sea, in Yorkshire; most of the material was dug out from an old heap of refuse thrown aside during boring operations, but the plant-bed was also investigated *in situ*.[1]

The locality is mentioned on the 6-inch Ordnance Survey-maps as Marske Quarry; it is situated 1 mile directly south of Marske, and about 500 feet above sea-level. This plant-bed occurs low down in the Estuarine Series, and is probably of Lower Estuarine age; but in the neighbourhood of Marske, Mr. Hawell informs me, there is apparently no distinct line of division between the Lower and the Middle Estuarine Series.[2]

The generic name *Dictyozamites* was proposed by Oldham in 1862[3] for some pinnate fronds discovered in strata of laminated clay, converted by igneous agency into a porcellanous rock, at the eastern end of the Puchwara Pass in the Rajmahal Hills. The fragments represented in figs. 5–8 (Pl. XV) were drawn from a piece of this rock in the British Museum (Natural History) Collection.[4] Morris, as joint author with Oldham of the first volume of the 'Fossil Flora of India,' referred the specimens to Gutbier's genus *Dictyopteris*, a term applied to certain Palæozoic species agreeing in all respects, except in the reticulate venation of the pinnules, with the well-known genus *Neuropteris*. Presl's generic term *Linopteris*[5] has been substituted by some authors for *Dictyopteris*. Morris instituted the species *Dictyopteris falcata* for the Rajmahal plant, describing certain specimens as *D. falcata*, var. *obtusifolia*.[6] The name *Dictyopteris* expressed Morris's view that the leaves were those

[1] Mr. Hawell kindly supplied me with this information, and I am indebted to him for generously allowing me to describe the specimens which form the subject of this communication.

[2] For the geological structure of this part of Yorkshire, see Fox-Strangways (92). [Numerals in parentheses throughout this paper refer to the Bibliography on p. 230.]

[3] Oldham & Morris (63) p. 38.

[4] Specimen No. 52546.

[5] For a figure of *Linopteris*, see Zeiller (00) p. 108.

[6] Oldham & Morris (63) pl. xxiv, fig. 2.

of a fern, an opinion shared by Zigno, to whom specimens were sent for examination. The view usually held that *Neuropteris* is a genus of Ferns has not as yet been demonstrated by the evidence of satisfactory fertile fronds, and we should probably better express the botanical position of this provisional genus by including it as a member of that important Palæozoic class the Cycadofilices, than by retaining it among the Ferns. Oldham, on the other hand, was of opinion that the plants referred to *Dictyopteris* were probably Cycads, and to give expression to this view he proposed the name *Dictyozamites* for the fragments of Indian leaves which bore the closest resemblance, except in the venation of the leaflets, to the genus *Otozamites*, adding the following diagnosis :—'Pinnis multinervis ; basi subauriculatis ; nervis dichotomis reticulatis.' [1]

In an earlier paper, Oldham [2] mentioned the occurrence of *Dictyopteris*, but without any discussion as to the probable nature of the leaves referred to this 'peculiar genus.'

In 1877 Feistmantel [3] described additional specimens from Amrapara and Golapili [4] and substituted the name *Dictyozamites indicus* for Morris's *Dictyopteris falcata*, including the forms originally separated as the variety *obtusifolia*. While Feistmantel was no doubt well advised in including the various forms under one designation, there was no need to discard Morris's specific name *falcata*. In justification of this change Feistmantel pointed out that the specific name *indicus* was appropriate as denoting that *Dictyozamites* is an Indian type,—a reason, in any case inadequate, which subsequent discoveries have rendered misleading. Another argument was that Morris's term implied that the falcate form of the pinnæ was a specific character, whereas for some specimens the descriptive epithet *falcata* was inaccurate.[5]

In 1876 Feistmantel published a paper in the 'Palæontographica'—'Ueber die Indischen Cycadeengattungen *Ptilophyllum*, Morr., & *Dictyozamites*, Oldh.,' [6] in which *Dictyozamites indicus* is thus defined :—

> 'Fronde simplici, elongata ; foliolis alternantibus ; aut brevioribus et obtusioribus, aut longioribus apicemque versus incurvatis vel falcatis ; solum media parte basis insertis aut sessilibus—aut paulo pedunculatis—angulis basalibus distincte auriculatis ; uno foliolo terminante. Nervis crebris, media basi eggredientibus, marginem versus irradiantibus—areolas formantibus. Areolis mediis elongatis subparallelis—areolis apicem marginemque versus brevioribus —polygonalibus.'

The pinnæ shown in figs. 5–8 (Pl. XV) are identical with the smaller forms of *Dictyozamites* as figured by Feistmantel from the Sripermatur Series [7] in the neighbourhood of Madras, which may be included stratigraphically in the Rajmahal Group.[8] The longest

[1] Oldham & Morris (63) p. 40.
[2] Oldham (60) p. 320.
[3] Feistmantel (77) pp. 69, 70 & pl. xlvi, figs. 7–8.
[4] Feistmantel (77^2) p. 18 & pl. ii, figs. 5–6.
[5] Feistmantel (76) pp. 19 & 20.
[6] *Ibid.* p. 18.
[7] Feistmantel (76) pl. vi, figs. 4 & 5.
[8] R. D. Oldham's edition of Medlicott & Blanford (93) p. 182.

pinna is slightly over 2 centimetres in length and has a breadth of 4 millimetres; the veins, not always accurately represented in Feistmantel's plates, are clearly defined. Most of the leaflets are imperfect, but in a few cases (Pl. XV, fig. 6) one is able to see that they were attached to the rachis by a small portion of the lamina occupying an approximately-median position on the basal end; the edges of the base are very slightly lobed.

On the same porcellanous slab numerous fragments of other fronds occur, which I am unable to distinguish from *Williamsonia pecten*.

The next contribution to our knowledge of Oldham's genus was made by Dr. Yokoyama,[1] who recorded the occurrence of the Indian type at Ozo in the Province of Koga and at Ushimari in the Province of Hida in Central Japan. Most of the Japanese specimens are referred to a variety of the Rajmahal type—*Dictyozamites indicus*, var. *distans*; but a new species was instituted by Yokoyama, under the name *D. grossinervis*, for a form of pinna characterized by a coarser form of reticulation.

In 1889 Prof. Nathorst published a paper 'Sur la Présence du Genre *Dictyozamites*, Oldham, dans les Couches jurassiques de Bornholm.'[2] The specimens, collected by Herre A. F. Carlson in 1885, in the neighbourhood of Hasle in Bornholm, were named by Prof. Nathorst *Dictyozamites Johnstrupi*. This species agrees in the habit of the frond with the Indian form, but differs slightly in the shape of the pinnæ and in their manner of attachment to the rachis of the frond. Mr. Hawell's discovery at Marske affords proof of the occurrence of Oldham's genus in a second European region of rocks, of approximately the same geological age as those of Bornholm.

Distribution of the Genus *Dictyozamites* in the Jurassic Period.

Dictyozamites falcatus (Morr.)	Rajmahal Series of India.
Dictyozamites falcatus (Morr.), var *distans*, Yok.	Central Japan.
Dictyozamites falcatus (Morr.), var. *grossinervis*, Yok.[3]	Central Japan.
Dictyozamites Johnstrupi, Nath.	Bornholm.
Dictyozamites Hawelli, sp. nov.	England (Marske, E. Yorks).

In the absence of reproductive organs it is impossible to speak with confidence as to the affinity of the genus. It has long been customary to include fossil fronds, which agree in their pinnate method of branching and in the form and arrangement of the pinnæ with the leaves of modern Cycads, in the class Cycadales. The monotypic Australian genus *Bowenia* is the only existing Cycad in

[1] Yokoyama (90) pp. 53, 55, pl. vii, fig. 10, pl. x, figs. 4–10, & pl. xi, fig. 5.

[2] Nathorst (89).

[3] I have reduced Dr. Yokoyama's species *D. grossinervis* to the rank of a variety, as the small fragments with the coarser type of venation seem to me to be more appropriately distinguished by the term *grossinervis*, used as the designation of a variety, than as defining a distinct species.

which the fronds are bipinnate. In some instances we possess information as to the nature of the stems which bore the fronds, and we are familiar with various types of Cycadean inflorescences. The genus *Williamsonia* is represented by the Jurassic species *W. gigas* (L. & H.) and *W. pecten* (Phill.), characterized by pinnate fronds closely resembling those of certain forms of modern Cycads; in the case of the former species we have some evidence as to the nature of the stem, which in external form was practically identical with the stems of *Macrozamia* or *Encephalartos* among existing genera.[1] I have elsewhere[2] shown that Williamson's opinion, expressed in his important memoir published in 1870,[3] as to the organic connection between the fronds originally named *Zamia gigas*, L. & H., and the peculiar reproductive shoots named by Carruthers *Williamsonia*,[4] is confirmed by the evidence of specimens in the Yates Collection in the Paris Natural History Museum.

It seems clear that the smaller form of *Williamsonia*, figured by Leckenby in 1864,[5] represents a reproductive organ of the plant which bore fronds previously known as *Pterophyllum pecten*, L. & H., and now referred to the genus *Williamsonia*.

Prof. Nathorst has clearly demonstrated an organic connection between a third type of *Williamsonia*, *W. angustifolia*, Nath., and leaves formerly placed in the genus *Anomozamites*.[6]

We have therefore sufficient evidence to justify the opinion, founded at first on the external resemblance of vegetative structures, that certain of the Cycad-like fronds of Mesozoic age have their nearest living representatives in the Cycadaceæ. On the other hand, there are numerous forms of pinnate leaves which we are as yet unable to associate with either stems or reproductive organs, but which it is reasonable to regard as fronds of Cycadean plants. Prof. Nathorst has recently suggested the term Cycadophyta[7] as a convenient designation for fossil Cycadean plants known only as isolated leaves. The morphology of the flowers of some of the Mesozoic Cycads differs in so marked a manner from those of recent forms, that it has been necessary to place them in a separate division—the Bennettitales—of which the English species *Bennettites Gibsonianus*, Carr.,[8] represents the typical example.

No specimens of the English *Williamsonia* have so far been discovered of which it is possible to make an anatomical examination; but it is clear that the type of reproductive shoot represented by Mr. Carruthers's genus is very closely allied to, if not generically identical with, *Bennettites*.[9] Other fossil reproductive organs are known which present a sufficiently close agreement with those of modern Cycads to warrant their inclusion with them in a separate

[1] Seward (00^3) p. 179.
[2] Seward (97) p. 274.
[3] Williamson (70).
[4] Carruthers (70).
[5] Leckenby (64) [*Palæozamia pecten*] pl. ix, fig. 4 *a*.
[6] Nathorst (80) & (02) pp. 9 *et seqq.*
[7] Nathorst (02) p. 3.
[8] Carruthers (70); Solms-Laubach (90). For an account of the male organs of *Bennettites*, see Wieland (99) (99^2) & (01).
[9] Seward (95) pp. 146 *et seqq.*

division, the Cycadales. We may, therefore, as Prof. Nathorst has suggested, employ the term Cycadophyta as a group-name for Cycadean plants, comprising the two subdivisions Cycadales and Bennettitales, the distinguishing characters of which are furnished by the reproductive structures. In dealing with the numerous fossil leaves which are in all probability Cycadean, but cannot, through lack of evidence, be referred to one or other of the two subdivisions, we can best express our opinion as to their probable taxonomic position, and at the same time our ignorance as to their precise affinity, by speaking of them as members of the Cycadophyta.

CYCADOPHYTA, Nathorst.

[Kongl. Svensk. Vetenskaps-Akad. Handl. vol. xxxvi, no. 4, p. 3.]

Genus Dictyozamites, Oldham.

[Mem. Geol. Surv. India, Pal. Indica, ser. 2, vol. i, p. 40.]

Fronds pinnate, similar in habit to those of *Otozamites*; pinnæ sessile, or with a very short stalk, disposed in two alternate rows, and attached to the rachis either by the middle or by the lower half of the base. The basal free portion of the pinnæ is usually slightly auriculate. The central portion of the lamina of the pinnæ is occupied by veins which follow a longitudinal and approximately-parallel course, and are connected one with the other by oblique anastomoses; the veins of the median region give off branches which curve obliquely upward and downward to the margin of the leaflet, and by repeated cross-connections with one another divide the lamina into numerous polygonal meshes or reticula.

Stems and flowers unknown.

Dictyozamites Hawelli, sp. nov. (Pl XV, figs. 1–4.)

Fronds pinnate; pinnæ crowded, sessile, in two alternating rows, attached by a small portion of the lamina slightly below the middle of the base to the upper face of the rachis. The pinnæ are broadly linear in shape, and taper gradually to a bluntly rounded apex; the upper margin of the base is slightly auriculate, the lower margin rounded or very slightly auriculate.

Veins numerous; those in the median region are approximately parallel to the edges of the pinna, and from them branches are given off which pass obliquely upward and downward towards the margin of the lamina.

The material from Marske consists of small and imperfect pieces of fronds, but is sufficient to form the type of a distinct species, distinguished from *Dictyozamites falcatus* (Morr.) by the relatively greater breadth of the segments, their more linear instead of a falcate form, and by the attachment to the rachis being slightly below the middle of the pinna-base. From the Japanese type *D. Hawelli* differs in the more crowded arrangement of the segments and in their blunter apices

Dictyozamites Johnstrupi is characterized by the more strongly-curved pinnæ, with more sharply-pointed apices, and by their manner of attachment to the rachis.

Pl. XV, fig. 1. This specimen shows clearly the crowded arrangement of the pinnæ, and their manner of attachment to the axis of the frond. The upper face of the rachis is hidden by the bases of the pinnæ, as in the frond of *Otozamites*. The upper edge of the pinna-base is distinctly auriculate, while the lower edge appears to be merely rounded or very slightly lobed. The most complete pinna is 3 centimetres long and 11 millimetres broad; in the venation-characters the species agrees with the other types of the genus.

Fig. 2. This drawing gives an end-view of the lowest pinna of the specimen represented in fig. 1, and shows the small and narrow oval area *a* by which the leaflet was attached to the surface of the rachis *r*, agreeing in this respect with the method of articulation of the pinnæ of *Encephalartos* and certain other recent Cycads. The scar or attachment-area, *a*, is situated slightly below the middle of the pinna-base.

Fig. 3. In this fragment the venation is shown with great clearness; the most complete pinna has a length of 3·8 centimetres, tapering gradually towards the bluntly rounded apex.

Fig. 4. This enlarged drawing of a portion of one of the pinnæ shown in fig. 3 illustrates the characteristic venation of the genus.

Dictyozamites falcatus (Morr.). (Pl. XV, figs. 5–8.)

Fig. 5 represents a portion of a frond, drawn three times natural size, showing the form and manner of attachment of the bases of the pinnæ.

Figs. 6 & 7 illustrate the short, broad, and slightly-falcate form of the pinnæ of a small type of the Indian species. Fig. 7 is drawn natural size.

Fig. 8. A single pinna enlarged to show the venation, which agrees closely with that of *Dictyozamites Hawelli.*

Comparison of the Japanese, Indian, Bornholm, and English Mesozoic Floras.

It is of interest to compare the Mesozoic floras of Japan, India, Bornholm, and England, in each of which *Dictyozamites* is represented. The resemblance of one flora to another is usually obscured by the use of different generic or specific names for plants, which are either identical, or represent closely-allied members of the same family. This diversity in nomenclature is, to some extent, the result of geographical separation; an author naturally hesitates to assign the same specific name to plants from India and Europe unless the evidence as to identity is convincing. On the other hand, wide separation in space has often been allowed to exercise a misleading influence in the determination of species. Another

reason for the use of different names for plants, which are either specifically identical or very closely allied, is to be found in the individual preferences of authors in the choice of possible generic designations for a particular plant.

In order to obtain a clear idea of the botanical relationship of one flora to another it is essential to devise some method by which distinctions, either imaginary or exaggerated, between plants recorded by different writers under distinct names may be eliminated. As a standard of comparison we may take a list of the plants described from the Inferior-Oolite rocks of Yorkshire, and by adopting an uniform system of nomenclature, and regarding as representative species types that are either specifically identical or distinguished by characters that, so far as we can judge, are not of generic rank, we shall be in a better position to furnish an answer to the question—how closely do the widely separated floras of Japan and Western Europe resemble or differ from one another?

In the following lists (pp. 224–26) I have therefore made use of specific names in a wide sense. In taking considerable liberties with the nomenclature of other authors, I do not necessarily mean to express disagreement with them as regards their interpretation of affinity, but my aim is to avoid the danger of allowing slight differences—whether of specific rank or not—to obscure the broad relationships of floras. The method of comparison is adopted primarily for the purpose of instituting a botanical comparison, rather than with the view of expressing an opinion as to relative age or stratigraphical position. The data on which the lists are founded have been supplied by the works of Geyler,[1] Yokoyama,[2] and Nathorst[3] in the case of the flora of Japan, but the flora with with which we are more especially concerned is that described by Dr. Yokoyama in his earlier paper of 1886; by Oldham & Morris[4] and by Feistmantel[5] for the Indian species; and by Bartholin,[6] Möller,[7] and Hjorth[8] for Bornholm.

The welcome memoir by Dr. Möller on the flora of Bornholm deals only with the Pteridophyta, but we may look forward to a completion of his valuable investigations at an early date. [Since this paper on *Dictyozamites* was read, Dr. Möller's second memoir on the Bornholm Flora has been published; see Möller (03) in the Bibliography, p. 231.]

In order to avoid misunderstanding, the names employed by the authors of the floras of Japan, India, and Bornholm are added in square brackets in cases where their nomenclature or determination does not agree with that which I have adopted. The initial letters Y, F, N, B, and M (Yokoyama, Feistmantel, Nathorst, Bartholin, and Möller), placed after the specific names in the last three columns, serve as a guide to the 'Floras' from which the species are quoted.

[1] Geyler (77).
[2] Yokoyama (90) & (95).
[3] Nathorst (90).
[4] Oldham & Morris (63).
[5] Feistmantel (77) & (77^2).
[6] Bartholin (92) & (94).
[7] Möller (02).
[8] Hjorth (99).

England.	Japan.	India.	Bornholm.
Equisetales.			
Equisetites columnaris, Brongn.	The equisetaceous plant named by Dr. Yokoyama *Equisetum ushimarense* agrees closely with the European Wealden species *Equisetites Burchardti*, Dunk.[1]	Cf. *Equisetites rajmahalensis*. F.	Cf. *Equisetites columnaris*. [*Equisetum Muensteri* and *E.* cf. *Lyelli*. M.] The stems of *Equisetites* figured by Bartholin and Möller bear a resemblance to the smaller forms of *E. columnaris*.
Lycopodiales.			
Lycopodites falcatus, L. & H.	Cf. *Lycopodites* sp. (The fragments figured by Prof. Nathorst[2] appear to be too small to identify with any certainty.)	*Lycopodites falcatus*. [*Cheirolepis gracilis*. F.]	*L. falcatus*. M.
Filicales.			
Matonidium Gœpperti (Ett.).			
Laccopteris polypodioides (Brongn.).	....	....	*Laccopteris polypodioides*. M.
L. Woodwardi (Leck.)...	....	....	*L. Woodwardi*. [*Microdictyon Woodwardi*. M.]
Todites Williamsoni (Brongn.).	Cf. *Todites Williamsoni*. [*Asplenium whitbiense* (Brongn.). Y.]		
Coniopteris hymenophylloides (Brongn.).	? *Coniopteris hymenophylloides*. [*Dicksonia nephrocarpa*. Y.]	*Coniopteris hymenophylloides*. [*Hymenophyllites Bunburyanus*. F.; *Sphenopteris arguta*. F.]	*Coniopteris hymenophylloides*. [*Sphenopteris hymenophylloides* and *Dicksonia Pingelii*. M.]
C. quinqueloba (Phill.).			
C. arguta (L. & H.)......	*Cladophlebis Dunkeri* (Schimp.). (This Wealden type[3] is hardly distinguishable from *C. arguta*.) [*Pecopteris exilis*. Y.; *P. Geyleriana*. N.]	Cf. *Cladophlebis arguta*. [*Pecopteris lobata*. F.]	Cf. *Cladophlebis arguta*. [*Thaumatopteris gracilis*. M.]
Dictyophyllum rugosum, L. & H.	....	....	*Dictyophyllum rugosum*. [*D. Muensteri*; *D. acutilobum*; *D. Nilssonia*. M.]
Klukia exilis (Phill.).			
Ruffordia Gœpperti (Dunk.).			
Cladophlebis denticulata (Brongn.).	Cf. *Cladophlebis denticulata*. [*Asplenium distans*. Y.] [*Cladophlebis* sp. N.]	*Cladophlebis denticulata* [*Alethopteris indica*. F.] [*Asplenites macrocarpus*. F.]	Cf. *Cl. denticulata*. [*Cl. nebbensis*. M.]
Cl. lobifolia (Phill.)......	....	....	*Cladophlebis lobifolia*. [*Dicksonia lobifolia*. M.]
Sphenopteris princeps, Presl.	....	....	*Sphenopteris princeps*. [*Acrostichides princeps*. M.]

[1] Seward (94) p. 29. [2] Nathorst (90) pl. ii, fig. 3.
[3] Seward (94) p. 100 & pl. vii, fig. 3.

England.	Japan.	India.	Bornholm.
Filicales (*cont.*).			
Sphenopteris Williamsoni, Brongn.			
Sph. Murrayana (Brongn.)			
Tæniopteris vittata (Brongn.).	....	Cf. *Tæniopteris vittata*. [*Angiopteridium ensis*. F.]	Cf. *Tæniopteris vittata*. [*T. tenuinervis*, Brauns. M (*pars*).]
T. major, L. & H.	....	Cf. *Tæniopteris major*. [*Macrotæniopteris crassinervis* and *M. ovata*. F.]	Cf. *Tæniopteris major*. [*T. tenuinervis*. M (*pars*).]
Sagenopteris Phillipsi (Brongn.).	....	....	*Sagenopteris Phillipsi*. M.
Pachypteris lanceolata (Brongn.).	....	Cf. *Pachypteris lanceolata*. [*Dichopteris ellorensis*. F.]	*Pachypteris lanceolata*. [*Cycadopteris heterophylla*. M.]
Cycadophyta.			
Williamsonia gigas (L. & H.).	....	Cf. *Williamsonia gigas*.	
W. pecten (Phill.)	....	*W. pecten*. [*Ptilophyllum acutifolium*, *Pt. cutchense*, and cf. *Otozamites acutifolius*. F.]	
Anomozamites Nilssoni (Phill.).	....	....	Cf. *Anomozamites Nilssoni*. [? *Nilssonia Muensteri*, Schimp. B (*pars*).]
	Nilssonia, cf. *schaumburgensis* (Dunk.). (Probably identical with Dunker's Wealden species.[1])		
Otozamites Beani (L. & H.).	....	....	Cf. *Otozamites Beani*. [*O. obtusus*. B.]
O. Bunburyanus, Zigno.			
O. graphicus (Leck. *ex* Bean MS.).			
O. acuminatus (L. & H.).			
O. parallelus, Phill. ...	....	*Otozamites parallelus*. F. [Cf. also *O. Oldhami*. F.]	
O. obtusus (L. & H.), var. *ooliticus*.			
O. Feistmanteli, Zigno.	....	Cf. *O. Feistmanteli*. [*O. benhalensis* and *O. abbreviatus*. F.]	Cf. *O. Feistmanteli*. [*O. Reglei*. B.]
Nilssonia compta (Phill.)	....	Cf. *Nilssonia compta*. [*Pterophyllum princeps*. F.]	Cf. *Nilssonia compta*. [*N. polymorpha*, Schenk. B (*pars*).]
N. mediana (Leck. *ex* Bean MS.).	....	? Cf. *Nilssonia mediana*. [*Pterophyllum Carterianum* & *Pt. propinquum*. F.]	
N. tenuinervis, Nath.	Cf. *N. tenuinervis*. [*Nilssonia orientalis*, Heer. Y.]	....	*Nilssonia tenuinervis*. [*N. polymorpha*. B (*pars*).]

[1] Seward (95) p. 53.

England.	Japan.	India.	Bornholm.
Cycadophyta (*cont.*).			
Ctenis falcata (L. & H.).	....	....	Cf. *Ctenis falcata.* [*Ctenis Nathorsti.* M.]
Ptilozamites Leckenbyi (Leck. *ex* Bean MS.).			
Dioonites Nathorsti, Sew.	....	Cf. *Dioonites Nathorsti.* [*Zamites proximus.* F.]	Cf. *Dioonites Nathorsti.* [? *Pterophyllum Braunianum,* Gœpp. B (*pars*).]
Podozamites lanceolatus (L. & H.).	*Podozamites lanceolatus.* Y.		
Ginkgoales.			
Ginkgo digitata (Brongn.).	*Ginkgo digitata.* Y. A species named by Dr. Yokoyama *Ginkgodium Nathorsti,* an abundant Japanese type, probably a member of the Ginkgoales, is not represented in the Yorkshire flora.	....	*Ginkgo digitata.* B.
G. whitbiensis, Nath.			
Baiera gracilis, Bunb.			
B. Lindleyana (Schimp.).			
B. Phillipsi, Nath.			
Beania gracilis, Carr.			
Czekanowskia Murrayana (L. & H.).	....	....	*Czekanowskia Murrayana.* [*Cz. rigida.* B.]
Coniferales.			
Araucarites Phillipsi, Carr.	....	Cf. *Araucarites Phillipsi.* [*A. cutchensis.* F.]	
Pagiophyllum Williamsoni (Brongn.).	....	Cf. *Pagiophyllum Williamsoni.* [*Cheirolepis,* cf. *Muensteri.* F.]	Cf. *Pagiophyllum Williamsoni.* [*P. peregrinum.* B.]
Cheirolepis setosus (Phill.).			
Brachyphyllum mamillare, Brongn.	....	Cf. *Brachyphyllum mamillare.* [*Echinostrobus indicus. E. rajmahalensis,* &c. F.]	
Taxites zamioides (Leck. *ex* Bean MS.).	....	*Taxites zamioides.* [*T. planus.* F.]	

Japan.

In has been pointed out in a previous publication that several of the Mesozoic species described by Geyler,[1] Yokoyama,[2] and Nathorst[3] are probably identical with European Wealden species. The flora including *Dictyozamites*, with which we are chiefly concerned, is referred by Dr. Yokoyama to the Bathonian stage of the Inferior

[1] Geyler (77).
[2] Yokoyama (90) & (95).
[3] Nathorst (90).

Oolite; the plants described by Prof. Nathorst and in a later paper [1] by Dr. Yokoyama were obtained from different localities, and probably belong to an uppermost Jurassic and Lower Cretaceous horizon. As regards the later floras, which contain several Wealden species, it is of interest to note the absence of *Weichselia Mantelli* (Brongn.), a species abundantly represented in the Wealden vegetation of Europe.[2]

India.

The Rajmahal Series of India, with which alone we are immediately concerned, contains, as Feistmantel pointed out, several forms which bear a close resemblance to types of Rhætic age, and there can be little doubt that this flora should be referred to a somewhat lower horizon than the Inferior-Oolite flora of England. In spite of its slightly more ancient facies, the Indian flora, as a whole, exhibits a close agreement in its composition with that of Yorkshire.

In the foregoing lists I have substituted the generic name *Williamsonia* for certain pinnate fronds from the Rajmahal Series, which it has been the general custom to include in Morris's genus *Ptilophyllum.* The use of the latter term, as one denoting Cycadean fronds peculiar to Indian floras and distinguished, by the manner of attachment and arrangement of the pinnæ, from European leaves of similar habit, has been one cause of exaggerating the differences between Indian and Western floras. Feistmantel, in his paper of 1876,[3] speaks of *Ptilophyllum*, like *Dictyozamites*, as an Indian genus, and the practice has been to regard species so named as essentially distinct from European types. In the British Museum Catalogue published in 1900,[4] I expressed the view that there is no difference, between the abundant fronds from the Inferior Oolite of Yorkshire formerly known as *Pterophyllum pecten*, L. & H., and certain Indian species referred to *Ptilophyllum.* This conclusion is based on the examination of several specimens of the Indian fronds and their comparison with the English forms. *Ptilophyllum cutchense* and *Pt. acutifolium* of Feistmantel appear to me, not merely generically but specifically, identical with the English species, and this opinion derives support from the association of both the Indian and English leaves with specimens of reproductive structures of the *Williamsonia*-type. There is no need to recapitulate the facts bearing on the probable connection between the small form of *Williamsonia*, named by Prof. Nathorst *W. Leckenbyi*,[5] and the fronds of *Pterophyllum pecten*, L. & H.; a conclusion arrived at by Mr. Carruthers in 1870,[6] and adopted by several authors. This question, as well as a fuller comparison of the Indian and European

[1] Yokoyama (95).
[2] Seward (94) & (00^2).
[3] Feistmantel (76) p. 5.
[4] Seward (00^3) p. 192.
[5] Nathorst (80).
[6] Carruthers (70) p. 694.

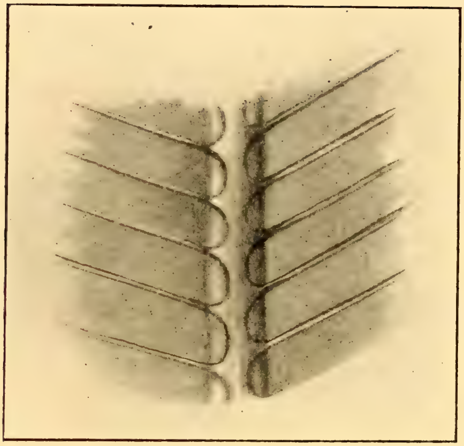
fronds, is dealt with more fully in my Jurassic Catalogues, from which one sentence may be quoted :—

'A careful examination of Morris's type-specimen of *Ptilophyllum cutchense* (in the Museum of the Geological Society of London), and of several other Indian specimens in the British Museum, has convinced me that a generic separation of the Indian and European fossils serves to mislead, and indicates a distinction which does not exist.'[1]

Morris's type-specimen is represented in the accompanying figure, approximately three times the natural size. As regards the arrangement of the pinnæ and the form of their bases, the specimen presents the closest agreement with *Williamsonia pecten.* In some fronds of *W. pecten* the pinnæ have broader bases, with the upper edge more or less auriculate ; a similar variation is seen also in the Indian fronds.[2] The following definition of *Ptilophyllum* as given by Morris contains nothing that is not equally applicable to the fronds of *Williamsonia pecten* :—

'Fronds pinnate, pinnæ closely approximated, linear, lanceolate, more or less elongate, imbricate at the base, attached obliquely; base semicircular or rounded ; veins equal, slender, parallel.'[3]

Ptilophyllum cutchense of Morris
[=? *Williamsonia pecten* (L. & H.)]. (× 3.)



Type-specimen.
(Geological Society's Museum, No. 9941.)

Bornholm.

The flora described by Bartholin, and more recently by Dr. Möller, includes several English types from Inferior-Oolite rocks, but the occurrence of other forms identical with, and closely allied to, Liassic and Rhætic species leads me to assign it to a somewhat lower horizon than that of the Yorkshire plant-beds.

The foregoing lists do not include any of the extra-British plants which cannot be closely matched by species from the Yorkshire strata as tabulated in the first column. If we examine the complete lists of Japanese, Indian, and Bornholm plants, disregarding such

[1] Seward (00^3) p. 193.
[2] See Feistmantel (76) pls. i–iv, and Seward (00^3) pl. iii & text-figs. 31–34.
[3] Morris (40) expl. of pl. xxi.

species as are founded on inadequate evidence, with a view to discover the chief distinguishing features which they exhibit, as compared with the Jurassic vegetation of England, we find very little indication of any but minor differences. The Bornholm flora is essentially of the same general botanical type as that of Yorkshire, the chief distinguishing features being due to the greater resemblance, as regards certain types, to such Rhætic floras as those of Franconia [1] and Scania [2]; but these differences are rather of the nature of the relative representation of particular families, than of a kind that one would expect to find had the vegetation of the two regions flourished under different conditions. Taking the two European floras together, and contrasting them with those of Japan and India, we note the prominence of the Matonineæ [3] (*Matonidium*, *Laccopteris*) and the Dipteridinæ,[4] *Dictyophyllum* and *Protorhipis* [5] (including species of *Hausmannia* of Möller), as contrasted with the apparent absence of these families of Ferns in the Eastern floras. Similarly the Ginkgoales [6] are not represented by any species which we can assign with confidence to either *Ginkgo* or *Baiera* in the Indian flora. One of the genera recorded from India, and not represented in the floras of Yorkshire or Bornholm, is *Cycadites*, but the Rajmahal forms of this genus may well be identical with a European species, *Cycadites rectangularis*, which occurs in the Liassic strata of England and in the Rhætic flora of Franconia.

In all the floras Cycadean plants play an important part. With regard to *Williamsonia* we have proof of its occurrence, in both India and Western Europe, supplied by the presence of reproductive organs; but the other Cycadophyta common to the different regions are represented almost solely by vegetative fragments.

A striking agreement, as regards the Ferns represented in the Eastern and Western floras, is clearly brought out in the foregoing lists. The Conifers of India and England agree in including representatives of *Araucarites*, but for the rest a comparison as regards family or generic identity is almost impossible in the absence of well-preserved cones. Such vegetative specimens as occur in the four floras appear to be of similar type, and we are justified in the conclusion that there is no evidence of any striking contrast between the Coniferæ of the East and the West. The character of the vegetation of the world from the Upper Triassic Period to the Wealden seems to have been remarkably uniform and constant in its main features. On a future occasion I hope to discuss in greater detail the distribution and composition of the various floras of Mesozoic type. The marked contrast exhibited by the Palæozoic vegetation on the one hand, and the Tertiary vegetation (including that of the greater part of the Cretaceous Era) on the other, to that which flourished through the whole Jurassic Era is a striking fact, well worthy of more critical and extensive consideration than it has so far received.

[1] Schenk (67).
[2] Nathorst (78) (78[2]) & (78[3]).
[3] Seward (99).
[4] See also Zeiller (97).
[5] Seward & Dale (01).
[6] Seward & Gowan (00).

Conclusion.

The main object of this paper is to record the occurrence in the Jurassic plant-beds of Yorkshire of a genus previously supposed to be confined to Japan, India, and Bornholm. A comparison of the Lower Jurassic flora from the Rajmahal Series of India with European floras reveals a greater similarity between the vegetation of Eastern and Western regions during part, at least, of the Mesozoic Era than is usually admitted. The differences between Mesozoic floras of approximately the same geological age are for the most part few and unimportant, when we consider their wide geographical separation.

Equisetaceous plants are practically ubiquitous; several ferns of apparently the same species occur in the far East and in Western Europe; Cycadaceous plants are represented by cosmopolitan types, and the same may be said of the genus *Araucarites* and other members of the Coniferæ. The most noteworthy exceptions are afforded by the Mesozoic representatives of the two isolated recent ferns *Matonia*[1] and *Dipteris*[2]; these two families—each with a surviving genus—played a conspicuous part in the vegetation of the Rhætic and succeeding Jurassic periods in Europe and, to a less extent, in North America, but we have no satisfactory records of their existence in India or Japan. A similar state of things is illustrated by the Ginkgoales, the class of which the maidenhair tree of China and Japan (*Ginkgo biloba*[3]) forms the solitary survivor; the abundance of both *Ginkgo* and *Baiera* in Europe is in striking contrast to their almost complete absence in India.

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[1] Seward (99).
[2] Seward & Dale (01).
[3] Seward & Gowan (00)

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EXPLANATION OF PLATE XV.

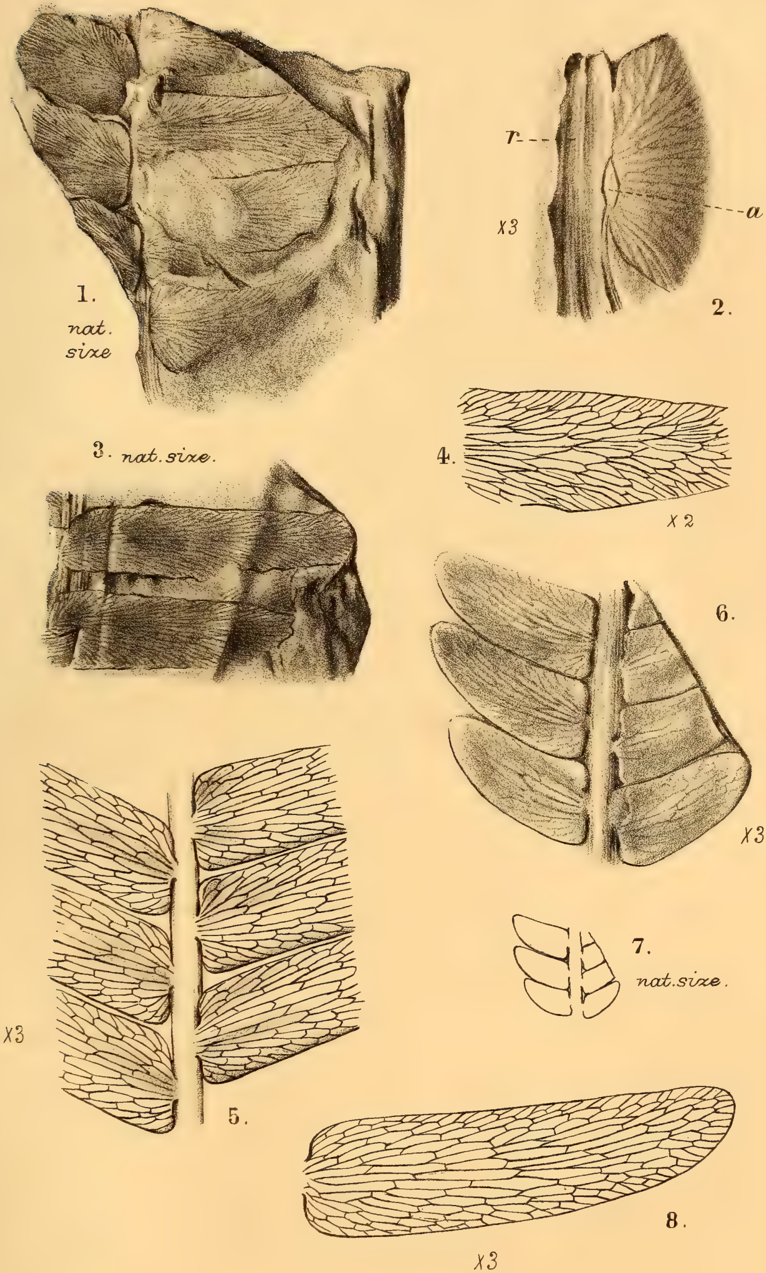
Fig. 1. *Dictyozamites Hawelli*, sp. nov. Natural size.
2. *D. Hawelli*. Base of the lowest pinna shown in fig. 1: a = surface by which the pinna was attached to the rachis; r = rachis of frond. Enlarged three times natural size.
3. *D. Hawelli*. Natural size.
4. *D. Hawelli*. Portion of one of the pinnæ shown in fig. 3. Enlarged twice natural size.
5. *D. falcatus* (Morr.). × 3.
6. *D. falcatus* (Morr.). × 3.
7. *D. falcatus* (Morr.). The portion shown in fig. 6 represented natural size.
8. *D. falcatus* (Morr.). Single pinna, showing venation. × 3.

[The specimens of *D. Hawelli* are from Mr. Hawell's collection, and are to be deposited in the British Museum (Nat. Hist.); the drawings of *D. falcatus* were made from specimen No. 52546 in that Museum.]

DISCUSSION.

The PRESIDENT spoke of the geological interest of this paper, as giving a fresh example of a fact familiar to many palæontologists who had devoted themselves to a single and well-defined group of fossils, namely, the close similarity of the collective forms belonging to that group occurring on about the same geological horizon in different regions of the globe. It was often a grave difficulty to decide whether the minor dissimilarities were of sufficient importance to warrant the present distinctions in nomenclature. The resemblances and differences no doubt both existed, and neither should be ignored; but in most cases, as shown by the Author in the present instance, the resemblances were of the higher systematic consequence. The great similarity between the Mesozoic vegetation of the Eastern and Western regions pointed out by the Author was of extreme interest; and when one bore in mind the great contrast between the Permo-Carboniferous flora and the Mesozoic flora of the Northern Hemisphere, and the fact that the *Glossopteris*-flora had already appeared in the Southern Hemisphere in later Permo-Carboniferous times, the Author's views seemed to have a high theoretical significance.

Dr. BLANFORD remarked that the paper was of great interest, and expressed gratitude to the Author for light thrown on an important portion of the world's history. The history of the genus *Dictyozamites* commenced in India. Some impressions of leaves in the Rajmahal Beds—shales interstratified with doleritic lava-flows—were at first referred to a fern, *Dictyopteris*, but subsequently were recognized as belonging to a Cycad and renamed *Dictyozamites*. The discovery of the same genus in the various regions recorded by the Author tended to link together the scattered occurrences of the Jurassic flora in the Northern Hemisphere. But this flora—or, rather, the Mesozoic flora as a whole, as defined by the Author—appeared to have been of worldwide distribution, and, with the possible exception of a Devonian flora, to have been the earliest that was known to have been generally distributed. Representatives of it had been found in South Africa and Australia, and recently



G.M. Woodward lith.

Mintern Bros. imp.

DICTYOZAMITES.

large collections belonging to it, made in Argentina, had been described by Dr. Kurtz and Dr. Bodenbender. Nor was this the only interesting fact about the plant-life of Mesozoic times. In Upper Palæozoic days two very distinct floras co-existed : the Northern or *Lepidodendron*- and *Sigillaria*-flora of the British Coal-Measures, and the Southern or *Glossopteris*-flora of Australia, India, South Africa, and South America. Some slight intermixture of the floras existed in the two last-named areas; none had been detected in Australia or India. But the earliest Mesozoic flora of Europe, the Triassic, which differed completely from the Permian, contained several forms characteristic of the *Glossopteris*-flora, and very probably might have been derived from the latter. The Mesozoic flora, as the Author had pointed out, prevailed up to the earlier part of the Cretaceous Period, but was replaced in Upper Cretaceous times by the modern flora, abounding in Angiosperms ; and this flora had continued down to the present day. The Mesozoic flora was perhaps derived from the Southern Hemisphere ; but the origin of the Tertiary and recent flora was still one of the puzzles of Geology.

19. *On a* Fossiliferous Band *at the* Top *of the* Lower Greensand *near* Leighton Buzzard (Bedfordshire).

By George William Lamplugh, Esq., F.G.S., and John Francis Walker, Esq., M.A., F.L.S., F.G.S. (Read February 4th, 1903.)

Part I.—General Description.

Introduction.

During an examination of the Lower Cretaceous outcrop in Bedfordshire by one of the writers in June 1902, he was delighted to find in the sands immediately below the base of the Gault-Clay, in the large sand-pits at Shenley Hill, $1\frac{1}{2}$ miles north-east of Leighton Buzzard, a richly-fossiliferous horizon which does not appear to have been hitherto noticed. Four separate visits were afterwards made by him to the locality, for the purpose of studying the section and collecting the fossils; but as these did not serve to exhaust the possibilities of the bed, the second author undertook to carry on the investigation, and for this purpose spent ten days on the ground in August. On the material thus jointly collected, along with further supplies since received from the quarrymen, the palæontological results given in this paper are based, while for the stratigraphical details of the sections, and for opinions expressed thereon, the first-named author is mainly responsible.

The nearest locality from which fossils have been previously recorded in the Lower Greensand of this part of England, lies between Great and Little Brickhill, 4 miles to the northward of Shenley Hill, where they were found abundantly in working a 'coprolite-bed' at the base of the Lower Greensand. The only other recorded occurrence of marine Lower Cretaceous fossils in Bedfordshire is at Potton, 19 miles to the north-eastward of Shenley Hill, where, in the workings of a pebbly 'coprolite-bed' which forms a band in the Greensands at a little distance above the base, numerous organic remains were discovered, but the majority were supposed to be derived from the underlying Jurassic rocks. The new locality is of especial interest in presenting the hitherto-unknown fauna of the highest part of the sandy deposits of the district. This fauna exhibits anomalous characters, which are without parallel in any other bed known to occur below the Gault in England. Indeed, if the stratigraphical evidence had been less definite, the fossil-band would probably have been classed on palæontological grounds with the Upper Greensand. For this reason the occurrence of the fossils is of more than local interest, and seems to deserve being brought under the notice of the Geological Society.

The lithological characters and stratigraphical relations of the fossil-band will be first described; and the palæontological evidence will be discussed afterwards.

Fig. 1.

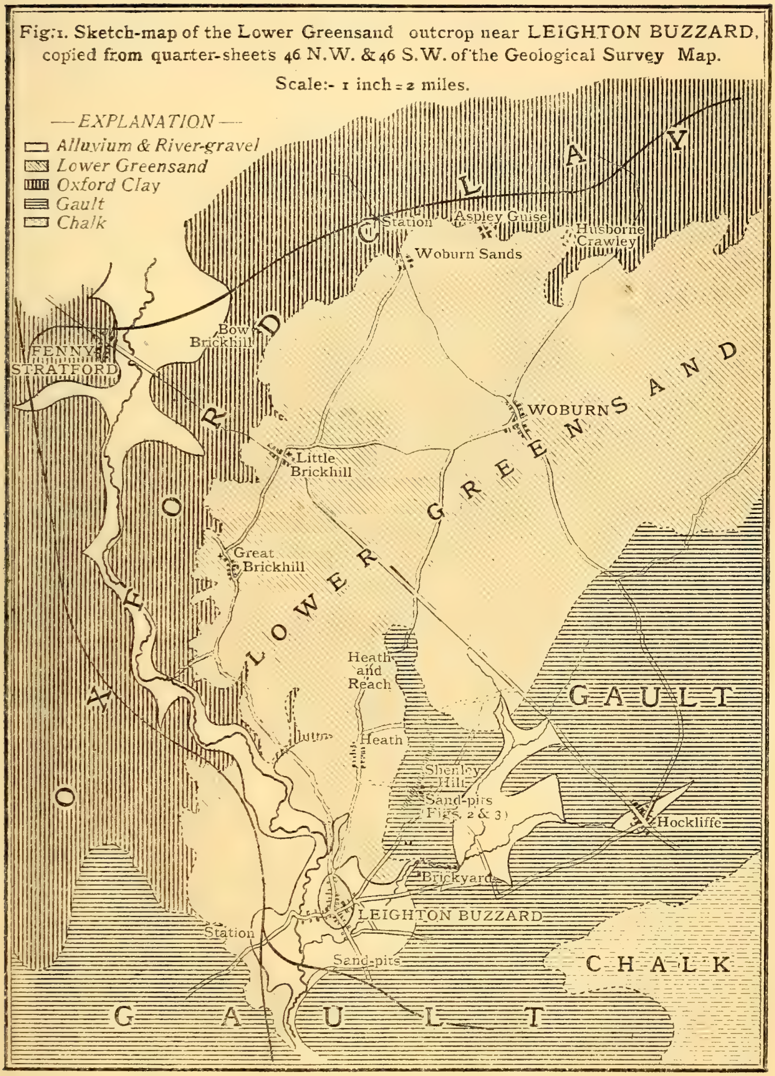


Fig. 1. Sketch-map of the Lower Greensand outcrop near LEIGHTON BUZZARD, copied from quarter-sheets 46 N.W. & 46 S.W. of the Geological Survey Map.
Scale:- 1 inch = 2 miles.
— EXPLANATION —
Alluvium & River-gravel
Lower Greensand
Oxford Clay
Gault
Chalk
OXFORD CLAY
LOWER GREENSAND
GAULT
CHALK
GAULT
Station
Aspley Guise
Husborne Crawley
Woburn Sands
Bow Brickhill
FENNY STRATFORD
WOBURN
Little Brickhill
Great Brickhill
Heath and Reach
Heath
Shenley Hill
Sand-pits Figs. 2 & 3
Hockliffe
Brickyard
LEIGHTON BUZZARD
Station
Sand-pits

Fig. 2.

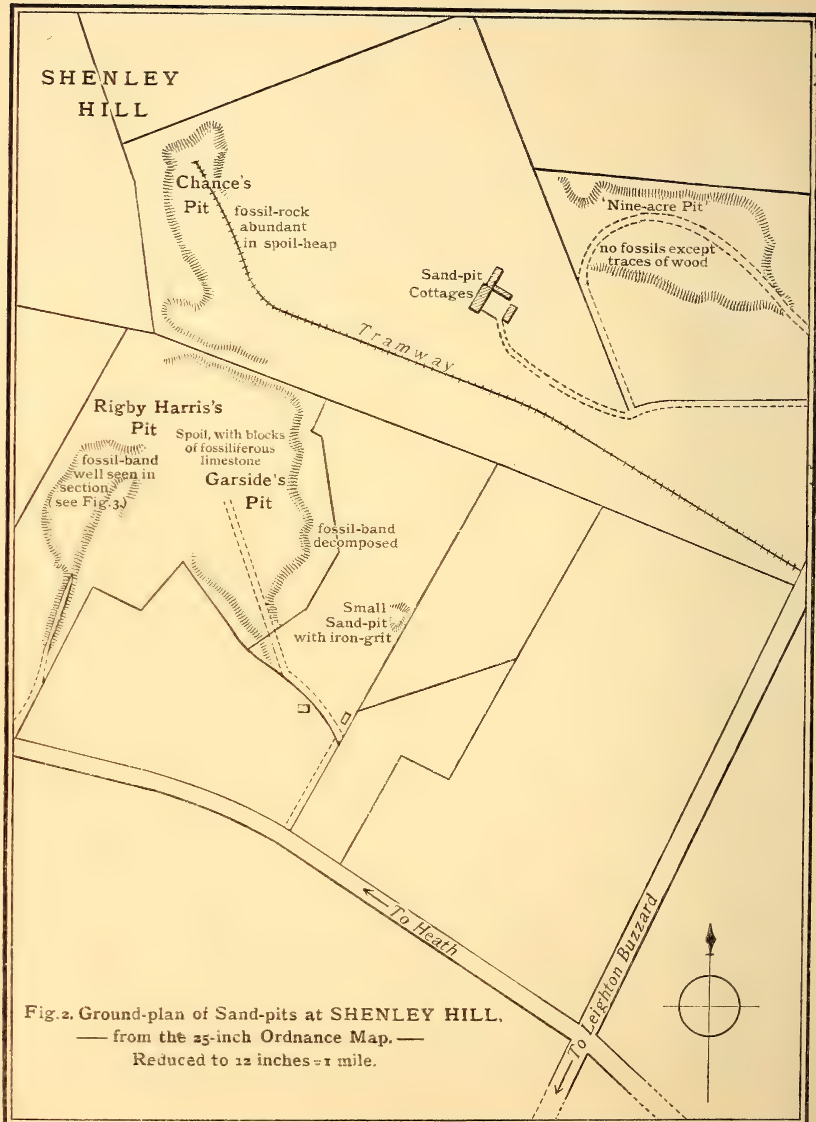


Fig. 2. Ground-plan of Sand-pits at SHENLEY HILL,
— from the 25-inch Ordnance Map. —
Reduced to 12 inches = 1 mile.

Description of the Sections.

As already mentioned, the exposures occur in a series of large sand-pits on the southern slope of Shenley Hill. Their position is indicated on the sketch-map (fig. 1, p. 235). These pits are opened mainly for the purpose of obtaining a clean white quartz-sand, known as 'silver-sand,' which is highly valued for filter-beds and other purposes, and is sent out of the district in large quantities.

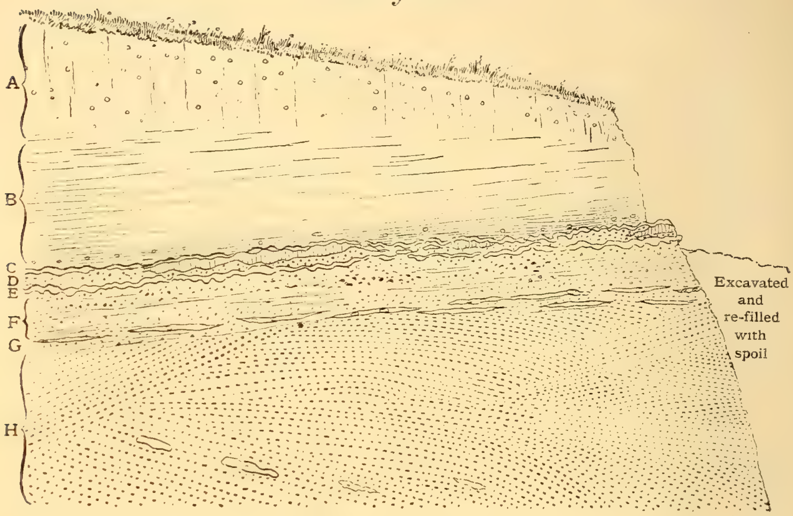
This material is dug in a group of contiguous pits (shown in the plan, fig. 2), among which the largest workings are known as 'Garside's Pit,' on the south-east; 'Rigby Harris's Pit,' conterminous with the former on the west; and 'Chance's Pit,' in the adjoining field north of Garside's. These pits cover an aggregate area of 400 yards by 300; the sand is removed to an average depth of 15 feet, and the excavation partly refilled with the heavy capping of Drift and Gault-Clay, which has to be taken off before the valuable 'silver-sand' can be reached. At first sight the sands appeared to be unfossiliferous, and indeed looked most unpromising for fossils.[1] But, while traversing the spoil-heaps during our first visit to the place, some blocks of hard, horny-looking, gritty limestone arrested our attention, and these on further examination were found to contain fossils. Search was made in the pit-sections for the bed from which the blocks had come, and the band was soon identified in Rigby Harris's Pit, where the working-face revealed the bed in place, as shown in fig. 3 (p. 238).

This section represents the clearest development of the fossil-band in the pits; but the bed may be traced, with constant minor variation, from point to point, wherever the junction of the Gault and Lower Greensand is visible in the sides of the pits. In the southern portion of Garside's Pit, however, as the bed approaches its outcrop at the surface from beneath the Gault it becomes decomposed to an ochreous marl, wherein organic remains are scarcely recognizable; and it has also been slightly disturbed by glacial agencies, which have mingled parts of the thin covering of Gault with the Boulder-Clay. In Chance's Pit, where the overlying Gault is 6 feet thick, covered by 4 or 5 feet of Boulder-Clay, the ironstone-floors associated with the calcareous concretions are as well-marked as in the section figured on p. 238; and between them we found casts of fossils in decomposing ochreous material, but saw none of the hard limestone-masses in place at the time of our visits, as they were obscured by talus. Some fossils *in situ* were, however, dug out by the foreman of the pit in the presence of one of the authors. Large blocks of the fossiliferous rock were

[1] This discouraging aspect of the sands explains how it has happened that the fossils have remained so long undiscovered. The pits were visited in 1897 by the Geologists' Association, and are described in Proc. Geol. Assoc. vol. xv, p. 184. In this description it is observed that the junction of the Gault and Lower Greensand 'is marked by a nodular bed of ochreous clay and ironstone,' and that 'drift-wood was found' in the pits, 'but no other fossils were seen.'

abundant on the tip-heap of this pit; and we were assured by the quarrymen that the stone occurred in the same position as in the other pits. Some of this stone was richly streaked and

Fig. 3.—*Section at the northern end of Rigby Harris's sand-pit, Shenley Hill.*



Scale:- 1 inch = 10 feet.

Brown clayey soil, with small stones. 1 foot.

A. Bluish-grey Boulder-Clay, composed of re-arranged Gault, speckled with small pieces of chalk, flint, iron-grit, and a few pebbles of quartzite, etc. .... 2 to 6 feet, merging downward into

B. Gault: bluish-grey shaly clay in the upper part, and dark blue below; with a few small pyritous clay-stone-nodules just above the base. 4 to 7 feet.

C. Irregular band of iron-grit, with smooth-worn wrinkled surface; usually dark liver-red, but in places crimson; occasionally split by ochreous partings and lenticles of coarse grit and iron-grit breccia. 1 to 3 inches.

D. Ochreous or greenish-yellow loamy sand, grit, and breccia; replaced here and there by lenticles of pale flesh-coloured or yellowish gritty limestone, full of fossils. 1 to 2 feet.

E. Undulating iron-grit band, as a rule sharply defined, but in one place approaching the upper band and there becoming lenticular and confused .... 2 to 3 inches.

F. Greyish greensand, moist and loamy, with clayey streaks and lenticles of pebbly grit .... 2 to 3 feet.

G. Lenticles of dark-red and ochreous iron-grit, with small included nodules of sandy pyritous clay-stone; streaks of fullers' earth, dark clayey greensand, and ochreous loam below; forming a well-defined band capping the 'silver-sands.' 1 to $1\frac{1}{2}$ feet.

H. 'Silver-sands': clean white or iron-stained sand, strongly cross-bedded, with sporadic masses of ironstone sometimes containing traces of wood .... 10 to 15 feet seen.

dappled with glauconite, but was otherwise exactly similar to that seen in the adjacent sections, and contained the same fossils. Most of these blocks have since been broken up at our instigation, and the fossils sent to one of the authors.

In all the sections there is a clear line of demarcation between the strongly current-bedded 'silver-sands' and the overlying more regularly-stratified loamy glauconitic sand, with its layers of iron-grit and fossiliferous concretions. This line of junction seems to form a definite floor, and to imply some degree of erosion and unconformity. Yet in a mass so irregularly-bedded as the Lower Greensand, such appearances are not unusual, and need not necessarily denote anything more than local erosion and re-arrangement.

The 'Silver-Sands.'

The silver-sands are sporadically indurated into irregular lumps and nodules of ironstone, in the larger of which traces of fossil wood, sometimes perforated by borers, may be occasionally detected[1]; but with this exception our search in them for organic remains was unsuccessful. Lithologically they somewhat resemble the 'Sandringham Sands'[2] of Norfolk, but probably occupy a higher stratigraphical position. The 'Nine-acre Pit,' shown in fig. 2 (p. 236), is entirely in these sands; and there are numerous other extensive excavations at the same and lower horizons in the tract of Lower Greensand north and west of Shenley Hill, but in none could we find any trace of fossils except wood. There are also very fine sections in ballast-pits on both sides of the branch-railway immediately south of Leighton, showing 20 to 30 feet of strongly current-bedded buff and ochreous sands, coarsely gritty in texture, with very little ironstone; but these sands are capped by Drift, and their junction with the Gault is not at present seen, although it must be nearly reached. No trace of the fossiliferous band was found in these sections; nor in the old sand-pits at Egginton, 1½ miles east of Shenley Hill, which are also close to the boundary of the Gault.

A striking feature, both in the 'silver-sands' and in the overlying sand, is the high degree of rounding and polishing exhibited by the larger quartz-grains and lydites. This feature is indeed prevalent in many sandy deposits between the Kimmeridge Clay and the Upper Cretaceous in England; as, for example, in the Spilsby Sandstone of Lincolnshire, in the Sandringham Sands of Norfolk, in parts of the Folkestone Sands of Kent, and in the Ironsands of Western Sussex. It has been previously pointed out by one of us, that where beds possessing this peculiarity are present in the Lower Cretaceous Series, a great change is usually observable in the fauna above and below such beds wherever fossil evidence is available; and the conclusion has been drawn that sands of this character denote periods of slow deposition on a current-swept sea-floor, whereon the same detritus was drifted to and fro and frequently redistributed, without much addition of new material.[3]

[1] The specimen of '*Cycadoidea Yatesii* from Leighton Buzzard,' described by Mr. W. Carruthers in Geol. Mag. vol. iv (1867) p. 199, and mentioned by Morris (*ibid.* p. 457), may have been obtained from these sands.

[2] 'The Borders of the Wash' Mem. Geol. Surv. (1899) p. 17.

[3] 'Summary of Progress for 1898' Mem. Geol. Surv. pp. 142–43.

By long-continued attrition under current-action, the sand-grains may eventually become nearly as well-polished, though not quite so well-rounded, as in desert blown-sands, to which this polishing has been considered (perhaps too exclusively) to be confined. The researches of Mr. A. R. Hunt upon the smoothly-rounded sands of the Skerries Shoal, off the coast of Devon, may be adduced as a modern illustration of this action.[1] It is especially noteworthy that phosphatic nodules are very frequently associated with these polished sands. Into this side-issue we do not propose to enter further at present, as the matter will be more conveniently discussed on some future occasion, in connection with the re-investigation of the fauna of the Lower-Greensand phosphate-beds.

The Iron-Grit Bands.

Additional proof of the slow rate of deposition is afforded by the floors of iron-grit, which are so strikingly developed immediately above and below the fossiliferous band at Shenley. Similar iron-stone occurs sporadically in nodules and irregular masses throughout the Lower Greensand of the Midland counties: its presence in the 'silver-sands' of the Shenley sections has already been noted, and it is plentiful also in the sand-pits at lower horizons between Leighton Buzzard and Woburn. In most cases it has clearly been formed subsequently to the period of accumulation of the sands, through the segregation of the iron-salts by percolating waters. Indeed, in some places the induration is probably still in progress. In a small opening south-east of Garside's Pit (shown in fig. 2, p. 236), where the sands crop out at the surface from beneath a thin wedge of Drift, there is at the top of the section a large mass of iron-grit, 2 to 5 feet thick, peculiarly hard and vitreous, and almost black in the middle of the blocks, in which apparently there has been some solution and redeposition of silica as well as of iron. This rock passes out downward, along planes of cross-bedding, into a bright orange-staining of the sands, and though these sands are very different in aspect from the white sands of adjacent sections, they are clearly part of the same mass. Here it is highly probable that the present position of the outcrop is responsible for the induration and staining.

The persistent undulating floors of iron-grit associated with the fossiliferous belt, however, though somewhat similar to the later concretions in appearance and composition, must have been formed very soon after the accumulation of the sands; for there is clear proof that they were in existence as rocky bands before the material now overlying them was deposited. Above the lower band are in places patches of coarse breccia, composed of flat fragments of iron-grit ranging up to 3 or 4 inches in diameter, more or less sub-angular, but with worn and polished surfaces, mixed with coarse quartz-grit and small 'lydite'-pebbles in a slightly-calcareous paste,

[1] 'The Evidence of the Skerries Shoal on the Wearing of Fine Sands by Waves' Trans. Devon. Assoc. Adv. Sci. vol. xix (1887) pp. 498-515.

among which brachiopods and other shells, with the tests converted into limonite and well-preserved, are sometimes embedded. From their size and character, it is clear that the larger fragments of this breccia cannot have been transported far. The iron-pan floor underlying these patches of breccia is polished and worn into little hollows, as though by the drifting of the overlying rubble and sand across it; and some large blocks on the tip-heap of Rigby Harris's Pit, apparently from this horizon, were encrusted on their worn irregular surfaces by adherent oysters and *Serpulæ*, clearly proving that the rock-band from which they came had constituted for a time the actual sea-floor.

It is scarcely likely that the sand could undergo cementation and induration at the surface immediately in contact with the sea-water. More probably the action took place at some little depth within the deposit, the hardened band being afterwards laid bare by currents of increased strength, which winnowed away all the loose material overlying it at this particular spot, until further erosion was checked by its presence. The fragments of iron-grit in the breccia, if not derived from portions of the same floor, may represent the remnants of impersistent masses which had formed at slightly higher levels and were let down piecemeal by the removal of their matrix. Obscure markings, suggestive of the almost obliterated casts of organisms, are frequently visible in this band of iron-grit; but it has yielded no fossil of which the nature could be definitely identified.

The persistent iron-pan floor which occurs above the fossiliferous belt and is directly overlain by the Gault-Clay, is of a character similar to that below the belt. It shows the same curiously-corrugated surface, and contains the same abundance of polished grit-grains. Indeed, the two occasionally come almost in contact with each other (as shown in fig. 3, p. 238), thus apparently marking off the intervening band into huge lenticles. During one of our visits to the section, the surface of the floor immediately underlying the Gault was freshly exposed in one part of the excavations over an area of several square yards, and exhibited a smooth-worn appearance, as though it had suffered attrition before the Gault-Clay was laid down upon it. The preservation of the fossiliferous limestone-lenticles is probably due to the protection afforded by these impervious iron-pan layers, which have shielded the bed between them from the solvent action of percolating waters.

The Lenticles of Fossiliferous Limestone.

The fossiliferous masses themselves present in their structure many points of interest. They vary from 2 or 3 to 10 feet or more in length, with a thickness never exceeding 2 feet and generally less. In the interior they are usually of very compact and horny texture, sometimes of a pale flesh-pink colour and sometimes yellowish, but they show every gradation between almost pure limestone and slightly calcareous grit. They are sprinkled through-

out, in varying abundance, with smooth shining grains of quartz, lydite, and dark iron-oxide; and occasionally with nests of coarse grit, bits of ironstone, and streaks of bright-green glauconite. At the exterior they are more predominantly gritty, softer, and of a yellow tint; and their surface is generally lumpy and nodular, being apparently studded with smaller concretions, resembling in this respect the limestone-masses in the 'Compound Nodular Band' at Speeton. They are generally more or less distinctly eroded at the upper surface, and sometimes perforated by borings filled in with dark greensand; therefore, like the iron-grit bands, they must have been sometimes actually uncovered on the sea-floor.

The smaller included concretions can often be recognized as the casts of shells, while in other cases they have a spongiform appearance. In general aspect these small nodules recall the 'coprolites' of Upware and Brickhill; but in composition they appear to be only sparingly phosphatic, and no phosphatized nodules like those of Potton, Upware, and Brickhill have been found. It is probable, however, that the small nodules may represent an early stage in the production of 'coprolites.' The same species of shells that occur in the condition of limonite in the patches of ironstone-breccia are found also in the calcitic state in the limestone and calcareous grit; and it is clear that the condition of preservation does not indicate any marked difference of age. Yet, although the limestone-lenticles occur only at one well-defined horizon (as shown in fig. 3, p. 238), we may notice a curious variation in their fossil contents, some blocks containing species in abundance which are rare or absent in other blocks, and almost every mass having its own faunistic individuality, although with certain species common to all. Thus, *Septifer lineatus* is very abundant in some blocks and absent from others; and so with most of the pectens and a few of the brachiopods, though certain species of the last-mentioned, notably *Terebratula capillata*, are present in nearly every block. Owing to this peculiarity, it is certain that the lists of fossils given on pp. 262–63 are not exhaustive, and that as new portions of the deposit are quarried, additions might be made to our collections.[1]

Taken in conjunction with the evidence already given for rearrangement and winnowing of the sands by current-action, this peculiar distribution of the fossils suggests that the limestone-masses have not been formed quite simultaneously, but that they probably represent shelly patches of the sea-floor where rapid consolidation took place at slightly different times, each locally-indurated patch in turn remaining fixed when the surrounding incoherent sand was swept away by the changeful currents. Under these circumstances the time-interval between the accretion of contiguous blocks may

[1] It is unlikely, however, that the fossils will be again procurable in such abundance as during our earlier visits; for at that time the limestone-blocks thrown aside during many years' working of the pits were available on the spoil-heaps, and most of these were broken up during our search. The quantity of this rock exposed in the actual working-faces of the pits at any time is comparatively limited.

have been of appreciable length; and meanwhile the fauna of any particular portion of the sea-floor may to some extent have responded to the changing conditions.

Condition of the Fossils.

Despite the unmistakable evidence for strong current-action during the accumulation of the sands, we find with some surprise that the shells embedded in the limestone, although fragile, are in splendid preservation, and rarely show even the slightest trace of abrasion. The delicate ornamentation of the striated and pustulated brachiopods, and of the pectens and other lamellibranchs, is generally as fresh and sharp as the most fastidious palæontologist could desire. Both valves are nearly always present and in position; and it is clear that the molluscs have flourished at the site where their shells now occur. In this respect the bed differs greatly from the Faringdon 'Sponge-Gravels' and from the Potton 'Phosphate-Bed,' in which nearly all the materials show signs of transportation; but it somewhat resembles the fossiliferous beds at Brickhill and at Upware, where many of the delicate shells are similarly, though not quite so perfectly, preserved and at the same time associated with much current-drifted detritus. To explain this anomaly, we may suppose that the molluscs have lived in clusters on the sea-floor during intervals when the strength of the currents at this particular spot was abated; and that a gritty calcareous mud was rapidly formed by the decay of the more perishable shells and other organisms, and thus provided a matrix which quickly became sufficiently consolidated to withstand the scouring action that recurred later when this spot was no longer sheltered from the sweep of the tides. That the calcareous cementing-matter has been mainly derived from this source is indicated by the differential state of preservation of the shells—those which were originally composed of calcite being beautifully preserved, while the species with shells of aragonite are scantily represented, and are generally in the form of casts. The classical researches of Dr. H. C. Sorby into the relative durability of fossils of aragonite and calcite, and their application by later workers to explain the selective preservation of organisms in limestone and other rocks, are too well-known to need more than a passing reference.

The presence of similar indurated calcareous masses in the 'Sponge-Gravels' of the 'Faringdon Pit' may here be recalled; but there is this difference in the conditions, that at Faringdon the concretions are developed in a matrix which is still crowded with organisms and abundantly calcareous, while at Shenley the fossils are confined to the blocks.

General Characters of the Fossils.

With regard to the palæontological aspect of the fossils, brachiopods are by far the most numerous, both in species and in individuals; next in abundance come the pectens, some of which are highly

ornamented and excellently preserved, but difficult to extract or clear from the matrix; the prettily-decorated mytiloid shell, *Septifer lineatus*, is also abundant in some of the lenticles, with its delicate markings intact. Large serrated spines of echinoderms occur scattered rather plentifully in most of the blocks, their characteristic oblique fracture being often visible on broken faces of the stone, although specimens could rarely be extracted in good condition; a few tests of echinoderms were also obtained, all referable to forms known in the Upper Greensand. Several fragments of carapaces of a crustacean were found, and have been identified as belonging to the genus *Plagiophthalmus*. Joints of a large round-stemmed crinoid, recalling the large *Bourgueticrinus* of the Red Chalk, were rather numerous in two or three of the blocks. *Serpulæ*, probably of two or three species; *Aviculæ*, not well preserved; a globose *Lima*; and some small irregular oysters; are present in most of the lenticles. Polyzoa, encrusting other fossils, are plentiful, but have not yet been worked out; ramose sponge-like bodies are also abundant, but sponges of the kind so plentiful at Faringdon and at Upware have not been found. Of the gasteropods which we obtained, some were in the condition of casts and none have as yet been specifically determined. A single fish-tooth, representing a species of *Scapanorhynchus*, is the only trace of vertebrate life that the bed has yielded to us.

Among the rarer fossils, the most important is the cast of portion of an ammonite in hard limestone, which led to close search being made for further examples, but without result. Although this specimen is scarcely adequate for specific identification, it shows sufficient of the shape and ornamentation of the original shell to prove that the species cannot be *Ammonites (Acanthoceras) mammillatus*, and also that it is unlikely to belong to any of the commoner Gault forms. It compares best with an ammonite collected by one of us from the Hythe Beds at Hythe, which is believed to be *Amm. (Acanthoceras) Milletianus*.[1]

The only other trace of *Ammonites* that we found was a small smooth-worn fragment of a whorl in the condition of an ironstone-pebble, which was of similar aspect to the fragments so abundant at Potton and other places.

Two fragmentary specimens of small *Belemnites*, probably immature, were recently obtained from the quarrymen. One specimen is still embedded in its matrix of gritty limestone, and the other has a little of the same material still adherent to it; so that there can be no doubt of their occurrence in the band. Neither, however, is sufficiently perfect for identification; but they bear no resemblance to the species occurring at Faringdon (*Belemnites speetonensis*, Pav.),[2] nor to any of the allied forms occurring in the 'Zone of *B. brunsvicensis*' of Speeton; they compare more closely with *B. minimus*, var. *attenuatus* of the Red Chalk and Gault, or with a small

[1] 'Summary of Progress for 1897' Mem. Geol. Surv. p. 129.
[2] Geol. Mag. 1903, p. 32.

unnamed belemnite occasionally found in the Hythe Beds, which is probably the young of *B. Ewaldi*, von Stromb.

The whole assemblage is peculiar, both in the presence of an admixture of forms which have not before been found together in the same bed, and in the absence of species commonly associated with those which it includes. Thus, while the general facies is closely allied to that of the Upper Greensand, we note the absence of such characteristic Upper-Greensand species as *Terebratella pectita* and *Pecten asper*; while the biplicated *Terebratula* and the *Terebrirostra* which are present are distinct varieties of the Upper-Greensand forms. On the other hand, in comparing the fauna with that of other sandy deposits of Lower-Greensand age, we find a few points of resemblance but still greater differences, both in the presence of numerous species absent from these beds, and in the absence of others, like *Terebratula sella* and *Exogyra sinuata*, which are so generally prevalent in them.

Notes on the Correlation and Classification of the Fossiliferous Band.

Our chief purpose in this paper has been to place on record a description of the Shenley fossiliferous bed and its fauna, without attempting a final judgment on the difficult question of its stratigraphical classification, which can be more adequately discussed when the researches of one of us into the British Lower Cretaceous system as a whole have reached a more advanced stage. It seems desirable, however, to point out the general bearing of our present results upon this question.

From the preceding palæontological notes and subsequent fossil-lists, it will be seen that the new fauna, though including some elements that link it to previously-known fossiliferous horizons of the Lower Greensand of the South-Midland and South-Eastern counties of England, presents on the whole a still closer connexion with the fauna of the Upper Greensand.

Nevertheless, the bed is distinctly seen to underlie the Gault-Clay throughout the sections, and moreover there seems also to be strong evidence that this clay must represent the Lower Gault. During our investigation, the clay in the sand-pit sections was not in good condition for yielding organic remains, and the only fossils observed in it by us were *Belemnites minimus* (abundant); *Inoceramus concentricus*; a few other ill-preserved shells, which were not identified; and the tooth of a fish. But at a distance of only 1100 yards to the southward of the sand-pits there is a brickyard in the Gault, from which, in a band midway in the clay, Mr. Jukes-Browne records an adequate list of ammonites and other fossils, including such unmistakable Lower-Gault forms as *Ammonites interruptus* and *Amm. Beudanti*, along with others which occur also in the Upper Gault.[1]

[1] 'The Cretaceous Rocks of Britain' vol. i, Mem. Geol. Surv. (1900) p. 285.

There is no reason to suspect any lateral change in the character of the Gault between the sand-pits and the brickyard; and indeed the presence of the worn surface on the iron-grit covering the sands: the sharp junction of this bed with the overlying clay: and the entirely-distinct facies of their faunas, render it almost inconceivable that there can be any lateral passage from clay to sand in this neighbourhood. We must therefore conclude that the overlying clay in the sand-pit sections represents Lower Gault, and that the fauna of the calcareous masses is of earlier date.

In its stratigraphical position and in its relations to the Gault above and to the sands below, the fossiliferous band at Shenley is closely analogous to the *Ammonites mammillatus*-bed at Folkestone. In the latter case, a fauna considered on questionable grounds to be of Upper Cretaceous age occurs in sands a few feet below the base of the Lower-Gault clays; its fossils, being mostly in the condition of phosphatized casts, are much less perfectly preserved than those of Shenley Hill. But a comparison of the respective faunas, curiously enough, lends little or no support to the correlation. As already stated, the single ammonite found at Shenley Hill is not *Ammonites mammillatus*; nor is it the second species of the bed at Folkestone, *Amm. Beudanti*, var. *ligatus* [1]; and, so far as we know at present, the only species which the beds have in common is *Pecten orbicularis*, a ubiquitous Cretaceous shell of no value in correlation.

The fossils of the *mammillatus*-bed show, indeed, much closer relationship with the Gault-fauna than do the Shenley fossils, which in their faunistic affinities seem to skip over the Gault and claim relationship with the Upper Greensand. On the whole, it appears probable that the Shenley fauna is somewhat older than that of the *mammillatus*-bed, and was separated by a longer time-interval from the beginning of Gault-conditions. Subsequent remarks touching the desirability of retaining the Shenley bed in the Lower Cretaceous system will apply, however, with almost equal force to the case of the zone of *Ammonites mammillatus*.

As to the relationship of the Shenley fauna with other fossiliferous horizons in the Lower Greensand, to which reference has been already made, it will be observed from the lists of fossils (pp. 262–63) that the bed has yielded a few species which occur also in the Faringdon 'Sponge-Gravels,' or at Brickhill, or Upware, or in the 'Bargate Beds' of Surrey. But the general assemblage at all these places, especially of the prevalent brachiopods, is entirely different from that at Shenley; and the absence of some of the commonest and most characteristic forms, along with the presence in abundance of others which are unknown at these places, make the difference of the fauna much more striking when the respective collections are examined than is apparent from the mere inspection of the fossil-lists. The lamellibranchs show a somewhat closer affinity to the

[1] 'The Cretaceous Rocks of Britain' vol. i, Mem. Geol. Surv. (1900) p. 443.

Lower-Greensand facies, especially in the case of the pectens; but the more thoroughly these fossils are studied, the more widely are they found to range and the more doubtful does their value in matters of correlation become. One of the Shenley pectens, for example, is stated by Mr. H. Woods, our chief authority on Cretaceous lamellibranchs, to present the distinguishing characteristics of *Pecten cinctus*, which has not hitherto been known to range higher than the Tealby Limestone or the lower part of the 'zone of *Belemnites brunsvicensis*.' But, as indicated in the list of fossils (p. 263), other Shenley lamellibranchs are known to range both above and below the horizon at which they are here found.

So far as we have been able to discover, the nearest approach to the Shenley fauna, more particularly as regards the brachiopods, is found in the fossils from the Tourtia of Belgium; and in this connection it is interesting to note that the Faringdon 'Sponge-Gravels' were at one time supposed to be of Upper-Greensand age, chiefly on account of the kinship of some of their brachiopods with those from the Tourtia.[1] Fortunately, one of us possesses a large series of the Belgian fossils, which has enabled us to compare the material in adequate quantity; and this comparison has shown that, while with some of the Shenley species there are minor differences such as are generally observable in forms from widely separated localities, the specific identity of many of the brachiopoda is unmistakable. These Tourtia-Beds (generally considered to be equivalent to the Upper Greensand of England) lie at the base of the Upper Cretaceous, where they mark a great unconformity, and apparently always rest directly upon a floor of Palæozoic rocks. Our discovery of a closely-corresponding fauna below the English Gault, by proving that many species supposed to be characteristic of the Upper Greensand were in existence before the deposition of the Gault, lends strong support to the more recent conclusions of M. H. Parent, that the Tourtia in different localities includes deposits ranging downward from the Albian into the upper part of the Aptian.[2]

The reason for the apparently-anomalous relations of the Shenley fauna is not far to seek. The deposits which represent the latest stages of the Lower Cretaceous system in England are of great irregularity, and only sparingly or sporadically fossiliferous; so that our knowledge of the life-history of the period after the deposition of the Atherfield Clay is scanty and imperfect. The accidental preservation of this fauna rich in brachiopods and other shells, at a higher horizon in the Lower Greensand than had previously yielded these fossils, has taught us that several species are of greater antiquity than had been supposed. The greater depth and muddy bottom of the Gault-sea were unfavourable to their continued

[1] T. Davidson, 'Monograph of the British Cretaceous Brachiopoda' Pal. Soc. vol. i (1852) p. 3.

[2] Ann. Soc. Géol. Nord, vol. xxi (1893) p. 205; see also discussion by A. J. Jukes-Browne in 'The Cretaceous Rocks of Britain' vol. i, Mem. Geol. Surv. (1900) p. 383.

existence in this place, and they disappeared; but were perpetuated in other places where the conditions were more suitable, and re-established themselves when the circumstances again became fitting. From the richness of the fauna both in species and individuals, it is unlikely that even at Shenley have we reached the lowest range of the so-called Upper Cretaceous forms; although, if it were possible to trace the fauna continuously downward, we should, of course, expect to find an increasing preponderance of exclusively Lower Cretaceous species.

The Lower Greensand of Central and Southern England, considered as a whole, forms a well-defined stratigraphical unit which has been classified as Lower Cretaceous ever since this division was established; and it seems to us to be undesirable to break up this classification, unless far stronger reasons are forthcoming than can be adduced in the present case. Setting other considerations aside, since the Shenley fossil-bed is lithologically part of the Lower Greensand, its fauna is entitled to be classed as Lower Cretaceous by priority of nomenclature, failing weightier cause for separating it therefrom.

Finally, as regards the palæontological evidence, it is certain that the prevalent conception in this country of what constitutes a Lower Cretaceous fauna will require considerable modification. Because it happens that the closing stages of the Lower Cretaceous Period in the South and South-East of England are represented mainly by unfossiliferous sands; and that the initial stages of the same period are represented in the same region by beds of freshwater origin: it has come to pass that our ideas concerning the marine fauna proper to the Lower Cretaceous have been based upon the fauna of only a very limited portion of the period. Consequently we find that a large number of the fossils of the 'coprolite-beds' at or near the base of the Lower Greensand have been rejected as 'derivatives,' on account of their Jurassic aspect or mineral condition; while as regards the uppermost beds, forming the zone of *Ammonites mammillatus*, because these have yielded fossils that show Upper Cretaceous affinities, it is claimed that they cannot be retained in the Lower Cretaceous but must be classed with the Gault. Too often do we lose sight of the essentially-arbitrary character of the boundaries adopted for our stratigraphical divisions, which are for the most part based upon local conditions that can only have persisted over areas of limited extent. And it is certain that the more fully we become acquainted with the sequence of events, the more difficult will it be, either from the stratigraphical or from the palæontological standpoint, to maintain our preconceived ideas as to the methods to be adopted in determining the limits of our systems. If our present Lower Cretaceous system is to be maintained, we shall have to recognize towards its base certain life-forms as Lower Cretaceous which have been hitherto regarded as exclusively Jurassic, and toward its summit other life-forms as Lower Cretaceous which were originally supposed to belong exclusively to the Upper Cretaceous. Difficulties of similar character

are being even more acutely felt by stratigraphists in this and other countries in the separation of the Permian and Carboniferous systems on the one hand, and of the Trias and Permian on the other. And we must be prepared either to find place for ambiguous developments of the kind discussed in this paper within the boundaries of our established systems; or to create a series of 'buffer-states,' under the designation of 'passage-beds,' to protect our systems from ever coming into contact where the succession is complete and where there may be neither stratigraphical nor biological break.

In concluding this part of our paper we wish to render thanks to Mr. E. T. Newton, F.R.S., F.G.S., for his great assistance in determining the echinodermata and other fossils, and for first pointing out to us the Upper Cretaceous affinities and anomalous characters of the fauna. We are also indebted to Mr. H. Woods, M.A., F.G.S., for the care which he has so willingly bestowed on the determination of the lamellibranchs.

Part II.—Description of the Brachiopoda.

[Plates XVI–XVIII.]

Terebratula capillata, d'Archiac. (Pl. XVI, figs. 1 *a*–6.)

1842. *Spondylus undulatus*, Geinitz, 'Char. d. Sächs.-Böhm. Kreidegeb.' pt. iii, p. 82.
1847. *Terebratula capillata*, d'Archiac, 'Fossiles du Tourtia' Mém. Soc. Géol. France, ser. 2, vol. ii, p. 323 & pl. xx, figs. 1–3.
1852. *Terebratula capillata*, Davidson, 'Brit. Cret. Brachiop.' Monogr. Pal. Soc. p. 46 & pl. v, fig. 12.
1868. *Terebratula capillata*, Schlœnbach, in Benecke's Geogn.-Paläont. Beiträge, vol. i, p. 454.
1871. *Terebratula capillata*, Quenstedt, 'Brachiopoden' [Petrefactenkunde Deutschlands, pt. i, vol. ii.] p. 385 & pl. xlviii, figs. 75–76.
1872. *Terebratula capillata*, Stoliczka, Pal. Indica, 'Cret. Fauna S. India' vol. iv, p. 23 & pl. vii, fig. 1.
1872. *Terebratula capillata*, Geinitz, 'Elbthalgebirge' p. 154 & pl. xxxiv, fig. 12.
1874. *Terebratula capillata*, Davidson, 'Brit. Cret. Brach.' Suppl. Monogr. Pal. Soc. p. 33 & pl. vii, fig. 2.
1878. *Terebratula capillata*, Deicke, 'Die Brachiop. der Tourtia von Mülheim' p. 16 & (pl.) figs. 7 *a*–7 *b*.

Of this characteristic species we have collected at Shenley a large number of specimens in all stages of growth, and many remarkable abnormal forms. The test is beautifully preserved, showing the small, narrow, capilliform, waving striæ intersected by concentric lines of growth. This species seems to be very variable in the convexity of the valves, in the relative length and width of the shell, and in the presence or absence of a wide fold at the front margin: all these varieties occur in the Tourtia of Belgium, as shown in a fine series sent by M. Piret, of Tournay. The globose specimens appear to be very similar to those found in the Red Chalk of Hunstanton (Norfolk), and at North Grimston (Yorkshire). Some of the specimens of *T. capillata* from Shenley so closely resemble those from Tournay in colour and in the composition of the matrix, that it would be impossible to separate them if they got mixed. D'Archiac

divided this species into minute varieties, which he distinguished by the letters *a* and *b*. We have found many other varieties which were not figured by him: if we compare the large wide forms with the more ovoid convex specimens, we find marked differences; but with the abundant material that we possess, we are able to connect together every variation of this species. *Terebratula capillata* is the characteristic fossil of the Shenley Bed: it occurs both in the calcareous and in the ferruginous part of the deposit, and also in the pink limestone.

The geographical range of *T. capillata* is very great. It has been found in the Tourtia of France, Belgium, also in Westphalia and near Dresden in Germany, and in Southern India. In England it occurs in the Red Chalk of Norfolk, Lincolnshire, and Yorkshire, and in the Aptian of Upware.

MEASUREMENTS OF *TEREBRATULA CAPILLATA* (IN MILLIMETRES).

	Length.	*Breadth.*	*Thickness.*	*Apical angle.*
A large, wide, flat specimen	35·0	33·5	16·50	100°
Specimen with wide fold	27·0	23·5	12·00	95°
Smaller specimen with wide fold...	19·5	17·5	8·50	91·5°
An ovoid globose specimen	21·0	18·5	12·50	92°
Young specimen	13·5	12·0	5·75	88°
Very young specimen	7·25	6·6	3·50	87·3°

A specimen of *T. capillata* from the Red Chalk of North Grimston (Yorkshire) yields the following measurements: length = 23·75 millimetres; breadth = 21 mm.; thickness = 14·25 mm.; and apical angle = 90°.

TEREBRATULA BIPLICATA, Sow., var. GIGANTEA, nobis. (Pl. XVI, figs. 7 *a*–7 *c*.)

1812. *Terebratula biplicata*, J. Sowerby, 'Mineral Conch.' vol. i, p. 201 & pl. xc.
1825. *Terebratula biplicata*, Sow. *ibid.* vol. v, p. 53 & pl. ccccxxxvii, figs. 2–3.
1847. *Terebratula Dutempleana*, A. d'Orbigny, 'Pal. Franç. Terr. Crét.' vol. iv, p. 93 & pl. dxi, figs. 1–8.
1852. *Terebratula obesa*, Davidson, 'Brit. Cret. Brachiop.' Monogr. Pal. Soc. p. 53 & pl. v, figs. 13–16.
1854. *Terebratula biplicata*, Davidson, *op. cit.* p. 55 & pl. vi, figs. 1–42.
1868. *Terebratula biplicata*, Schlœnbach, in Benecke's Geogn.-Paläont. Beiträge, vol. i, p. 433 & pl. xxi, figs. 1–3 & 6.
1871. *Terebratula biplicata*, Quenstedt, 'Brachiop.' p. 381 & pl. xlviii, figs. 61–67.
1872. *Terebratula biplicata*, Geinitz, 'Elbthalgebirge' p. 151 & pl. xxxiv, figs. 1–6.
1872. *Terebratula biplicata*, var. *Dutempleana*, Stoliczka, Pal. Indica, 'Cret. Fauna S. India' vol. iv, p. 20 & pl. v, figs. 1–3.
1874. *Terebratula biplicata*, Davidson, 'Brit. Cret. Brachiop.' Suppl. Monogr. Pal. Soc. p. 33 & pl. v, figs. 1–2.
1878. *Terebratula biplicata*, Deicke, 'Die Brachiop. der Tourtia von Mülheim' p. 10 & (pl.) fig. 1.
1900. *Terebratula biplicata*, Jukes-Browne, 'Gault & Upper Greensand of England' Mem. Geol. Surv. p. 58, fig. 24.

The large biplicated form which has been considered a giant variety of *Terebratula biplicata*, Sow. occurs in this bed. Davidson regarded it as a variety of *T. obesa*, but in his Supplement referred it to *T. biplicata*. For convenience, and to prevent confusion, we have given these specimens a varietal name, *gigantea.* The biggest specimen measures: in length, 74 millimetres; in breadth, 48 mm.; its greatest thickness = 38 mm.; and its apical angle = 43°

Some of the specimens of *Terebratula biplicata* var. *gigantea*, from Shenley, very closely resemble those from Warminster, having the large foramen and recurved beak. The plication of the front-margin varies in both localities, but some of the bigger Shenley specimens differ in having their sides more laterally compressed; some specimens from Warminster also show this.

TEREBRATULA BIPLICATA, var. DUTEMPLEANA. (Pl. XVII, figs. 1 *a* & 1 *b*.)

A specimen from Shenley appears to belong to this variety.

Dimensions:—length = 34·25 millimetres; breadth = 25 mm.; thickness = 22 mm.; and the apical angle = 61°.

The rarity of small biplicated *Terebratulæ* is a noteworthy feature of this deposit.

TEREBRATULA DEPRESSA, Lam., var. SHENLEYENSIS, nobis. (Pl. XVII, figs. 2 *a*–3 *b*.)

1819. *Terebratula depressa*, Lamarck, 'Hist. Nat. des Anim. sans Vert.' vol. vi, pt. i, p. 249.
1847. *Terebratula nerviensis*, d'Archiac, 'Fossiles du Tourtia' Mém. Soc. Géol. France, ser. 2, vol. ii, p. 313 & pl. xvii, figs. 2–10.
1850. *Terebratula depressa*, Davidson, Ann. & Mag. Nat. Hist. ser. 2, vol. v, p. 435 & pl. xiii, fig. 15.
1854. *Terebratula depressa*, Davidson, 'Brit. Cret. Brachiop.' Monogr. Pal. Soc. p. 70 & pl. ix, figs. 9–24.
1863. *Terebratula depressa*, E. Ray Lankester, 'Geologist' vol. vi, p. 414 & pl. xxi, figs. 5–7.
1864. *Terebratula depressa*, C. J. A. Meÿer, Geol. Mag. vol. i, p. 254 & pl. xi, figs. 15 *a*–15 *b*.
1868. *Terebratula depressa*, J. F. Walker, Geol. Mag. vol. v, p. 403 & pl. xviii, figs. 2–2 *a*.
1868. *Terebratula depressa*, Schlœnbach, in Benecke's Geogn.-Paläont. Beiträge, vol. i, p. 447 & pl. xxi, figs. 9 *a*–9 *b*.
1872. *Terebratula subdepressa*, Stoliczka, Pal. Indica, 'Cret. Fauna S. India' vol. iv, p. 16 & pl. iii, figs. 1–8.
1874. *Terebratula depressa*, Davidson, 'Brit. Cret. Brachiop.' Suppl. Monogr. Pal. Soc. p. 40 & pl. iv, figs. 1–4.
1878. *Terebratula depressa*, Deicke, 'Die Brachiop. der Tourtia von Mülheim' p. 14 & (pl.) figs. 4 *a*–4 *b*.

The material that we have collected at Shenley is not sufficient for the investigation of this species. The specimens appear to have a shorter beak, and to be more triangular in shape than any of the varieties figured by Vicomte d'Archiac. Some forms closely resemble those figured as *Terebratula subdepressa* by Stoliczka in the 'Cretaceous Brachiopoda of Southern India.'

Dimensions:—length = 47 millimetres; breadth = 38 mm.; thickness = 19·5; and the apical angle = 68°. In another specimen the length = 41 millimetres; breadth = 29·5 mm.; thickness = 15 mm.; and the apical angle = 63°.

TEREBRATULA MOUTONIANA, d'Orb., var. (Pl. XVII, figs. 4 *a* & 4 *b*.)

1847. *Terebratula Moutoniana*, A. d'Orbigny, 'Pal. Franç. Terr. Crét.' p. 89 & pl. dx, figs. 1–5.
1868. *Terebratula Moutoniana*, J. F. Walker, Geol. Mag. vol. v, p. 403 & pl. xviii, figs. 6 *a*–6 *b*.
1872. *Terebratula Moutoniana*, Pictet [Matér. p. la Paléont. suisse] 'Terr. Crét. Ste. Croix' pt. v, p. 86 & pl. cciii, figs. 1–3.

1874. *Terebratula Moutoniana*, Davidson, 'Brit. Cret. Brachiop.' Suppl. Monogr. Pal. Soc. p. 42 & pl. iv, figs. 11–13.
1883. *Terebratula Moutoniana*, var. *brickhillensis*, Keeping, 'Fossils & Pal. Affin. of Neocom. Deposits of Upware & Brickhill' [Sedgw. Prize Essay] p. 162.
1884. *Terebratula Moutoniana*, var. *brickhillensis*, Davidson, 'Brit. Cret. Brachiop.' App. to Suppl. (vol. v) Monogr. Pal. Soc. p. 251 & pl. xviii, fig. 8.

This species varies considerably in different localities. The Shenley specimens seem to be intermediate between the Upware and Brickhill forms. The test is smooth, exhibiting faint traces of striæ; the front margin shows a wide fold, the centre of the smaller valve being convex; the larger valve is depressed towards the front. This species and its varieties occur in the Aptian of France and Switzerland, as stated by various authorities. We have some specimens from the Tourtia of Tournay (Belgium) which closely resemble some of the Shenley shells; these have been regarded as a variety of *Terebratula Robertoni*, d'Archiac, but differ from his figure in having the smaller valve more globose, while the larger valve is slightly depressed towards the front margin.

Our specimens vary in the depth of the wide fold at the front margin, and in the relative length compared with the breadth; but we require more specimens before we can consider whether these should form a distinct variety.

The dimensions of a Shenley specimen are as follows:—length = 25 millimetres; breadth = 19 mm.; thickness = 11·75; and the apical angle = 72°.

TEREBRATULA BOUBEI, d'Archiac. (Pl. XVII, fig. 5.)

1847. *Terebratula Boubei*, d'Archiac, 'Fossiles du Tourtia' Mém. Soc. Géol. France, ser. 2, vol. ii, p. 320 & pl. xix, fig. 11.
1864. *Terebratula Boubei (?)* C. J. A. Meÿer, Geol. Mag. vol. i, p. 252 & pl. xii, figs. 5–7.

A *Terebratula* which occurs at Shenley appears to belong to this species. It is oval, elongated; the valves equally convex, showing lines of growth; surface smooth; beak elongated, slightly recurved, truncated by a circular foramen; the smaller valve shows a faint wide fold; the front margin is slightly angular, but in young specimens it is rounded.

Mr. Meÿer stated that he found single valves in the pebble-bed around Godalming, in Surrey, which may belong to this species. *T. Boubei* occurs in the Tourtia, near Tournay (Belgium). This species is not mentioned in Von Decken's list of the brachiopoda which occur in the Tourtia of Westphalia.

Dimensions:—length = 24·5 millimetres; breadth = 16·2 mm.; thickness = 11 mm.; and the apical angle = 56°.

TEREBRATULA OVATA, Sowerby. (Pl. XVII, figs. 6 *a* & 6 *b*.)

1812. *Terebratula ovata*, J. Sowerby, 'Min. Conch.' vol. i, p. 46 & pl. xv, fig. 3.
1847. *Terebratula lacrymosa*, A. d'Orbigny, 'Pal. Franç. Terr. Crét.' vol. iv, p. 99 & pl. dxii, figs. 6–11.
1852. *Terebratula ovata*, Davidson, 'Brit. Cret. Brachiop.' Monogr. Pal. Soc. p. 47 & pl. iv, figs. 6–13.

1874. *Terebratula ovata*, Davidson, 'Brit. Cret. Brachiop.' Suppl. Monogr. Pal. Soc. p. 32 & pl. ii, fig. 14.
1900. *Terebratula ovata*, Jukes-Browne, 'Gault & Upper Greensand of England' Mem. Geol. Surv. p. 65, fig. 40.

We have collected a few shells from Shenley which appear to belong to this species. They have the lateral and frontal margins sharper than the Warminster specimens, but do not differ from them more than this species varies in that locality. *Terebratula ovata* was well described and figured by Davidson; but unfortunately Sowerby figured a young specimen which does not show the characters of this species, and is one of the many instances in which the specimen first figured, the so-called 'type,' is not typical of the species.

The dimensions of a Shenley specimen are as follows:—length = 20 millimetres; breadth = 17 mm.; thickness = 9 mm.; and the apical angle = 90°.

T. ovata occurs in the Upper Greensand of Warminster and the Isle of Wight; in the Cenomanian of Devon, Somerset, and Dorset; and in France, in the Cenomanian near Havre.

TEREBRATULINA TRIANGULARIS, Etheridge. (Pl. XVII, fig. 7.)

1868. *Terebratulina rigida*, Schlœnbach, in Benecke's Geogn.-Paläont. Beiträge, vol. i, p. 455.
1874. *Terebratulina rigida*, Davidson, 'Brit. Cret. Brachiop.' Suppl. Monogr. Pal. Soc. p. 32.
1881. *Terebratulina striata*, var. *triangularis*, Etheridge, Mem. Geol. Surv. 'Geol. of Neighb. of Cambridge' p. 148 & pl. iii, fig. 15.
1884. *Terebratulina triangularis*, Davidson, 'Brit. Cret. Brachiop.' App. to Suppl. (vol. v) Monogr. Pal. Soc. p. 245 & pl. xviii, fig. 3.

We have found at Shenley a few specimens of a small *Terebratulina*, which appear to resemble closely the form that occurs in the Greensand of Cambridge, and in the Red Chalk of Hunstanton and Speeton. It is also found in the Tourtia of Essen, and the Cenomanian of Havre (France). It appears doubtful whether this species is Sowerby's *T. rigida*, which was found in the Chalk near Norwich; but, as we are informed that a monograph is being prepared on the *Terebratulinæ* of Europe by Dr. Kitchin, we will not further discuss the synonymy of this species.

Dimensions:—length = 6·5 millimetres; breadth = 5·25 mm.; thickness = 2·5 mm.; and the apical angle = 66°.

ZEILLERIA CONVEXIFORMIS, nobis. (Pl. XVII, figs. 8 *a*–8 *c*.)

Shell ovoid, globose, longer than wide; valves almost equally convex; greatest thickness about one-third from the posterior end; lateral margins regularly curved; front-margin rounded. Shell-surface smooth, showing concentric lines of growth. Larger valve convex, especially towards the beak, which is short, incurved, and truncated by a medium-sized foramen; beak-ridges concave; deltidium shallow, in two pieces; hinge-line curved. Smaller valve convex, the greatest convexity being about one-third of the shell; a dark line shows the presence of a median septum, hence the shell had a long loop.

Dimensions:—length = 18·5 millimetres; breadth = 15 mm.; thickness = 11 mm.; and the apical angle = 92·5°.

This species somewhat resembles *Zeilleria Juddi*, Walker, in its ovoid shape, but it is a more regular ovoid globose form, and is not laterally depressed, its beak is also shorter, and the beak-ridges are less concave. Probably our species belongs to the subgenus *Ornithella*.

Magas (?) latestriata, nobis. (Pl. XVII, figs. 9 *a*–9 *d*.)

Shell circular; the larger valve is much more convex than the smaller valve; the greatest thickness is about the centre of the shell; the lateral margins are sharp and regularly curved; front margin rounded, non-plicated, and not thickened. Shell-surface slightly granular, and ornamented on both valves by fine radiating striæ which are wide apart and reach to the beak. The larger valve has its greatest thickness near the centre, and is regularly convex; the striæ are best developed towards the lateral margins of the shell. The beak is short, nearly straight, and truncated by a large circular foramen; and it is separated from the hinge-line by a deltidium in two pieces. The beak-ridges are concave; the hinge-line is slightly curved. The smaller valve is slightly convex, the greatest width being about one-third of the distance from the posterior margin. A dark line, extending to about one-third of the shell, shows that it had a long loop.

Dimensions:—length = 18·5 millimetres; breadth = 17·5 mm.; thickness = 9·75 mm.; and the apical angle = 76·5°.

We have not been able to examine the loop of this shell, but it probably belongs to the genus *Magas*. In shape it somewhat resembles the large rounded specimens of *Zeilleria tamarinda*; but it is easily recognized by the ornamentation of its shell-surface, by the less proportional convexity of the smaller valve, by the beak being straighter, by the beak-ridges forming a smaller area, and by the absence of a fold on the front margin.

Magas orthiformis (d'Archiac). (Pl. XVII, figs. 10*a*, 10 *b*, & 11.)

1847. *Terebratula orthiformis*, d'Archiac, 'Fossiles du Tourtia' Mém. Soc. Géol. France, ser. 2, vol. ii, p. 333 & pl. xxii, fig. 4.
1852. *Magas orthiformis*, Davidson, 'Brit. Cret. Brachiop.' Monogr. Pal. Soc. p. 22, note.

We have obtained several specimens which we refer to this species; they appear to be plentiful at Shenley, but are difficult to find, on account of their small size. D'Archiac states that the shell is sufficiently characterized by its form, which recalls that of *Orthis*. The hinge-line is nearly straight, from the extremities of which the shell describes three-quarters of a circle; the larger valve is more convex than the smaller one, and has a short beak forming an obtuse angle with the hinge-line; foramen triangular; deltidium in two pieces, which do not surround the foramen. The surface of the shell is covered with faint radiating striæ, with transverse lines

of growth; some specimens show a dark line on the smaller valve, indicating the presence of a septum; the front margin is sharp and circular, showing no fold.

Davidson remarks that he had seen the interior of a specimen from the Tourtia of Belgium, which showed that it belonged to the genus *Magas*. This species occurs in the Tourtia round Tournay, where it is rare and not well preserved. It is not given in Von Decken's list of the species which occur in the Tourtia of Essen (Westphalia).

The Shenley specimens of *Magas orthiformis* show slight variations in the relative convexity of the valves, and in the thickening of the front margin; some attain a larger size than the shell figured by Vicomte d'Archiac.

MEASUREMENTS OF *MAGAS ORTHIFORMIS* (IN MILLIMETRES).

	Length.	*Breadth.*	*Thickness.*	*Apical angle.*
A large specimen	12·50	12·00	7·5	108°
Medium specimen............	8·75	10·25	4·0	95°
Small specimen...............	6·50	6·75	3·5	92°

TEREBRIROSTRA LYRA (Sowerby) var. INCURVIROSTRUM, nobis. (Pl. XVIII, figs. 1 *a*–2 *b*.)

1816. *Lyra Meadi*, Cumberland MS.
1818. *Terebratula lyra*, J. Sowerby, 'Min. Conch.' vol. ii, p. 87 & pl. cxxxviii, fig. 2.
1847. *Terebrirostra lyra*, A. d'Orbigny, 'Pal. Franç. Terr. Crét.' vol. iv, p. 129 & pl. dxix, figs. 11–19.
1852. *Terebrirostra lyra*, Davidson, 'Brit. Cret. Brachiop.' Monogr. Pal. Soc. p. 32 & pl. iii, figs. 17–28.
1900. *Terebrirostra lyra*, Jukes-Browne, 'Gault & Upper Greensand of England' [Cret. Rocks of Britain, vol. i] Mem. Geol. Surv. p. 66.

This remarkable brachiopod has been often figured (see Davidson's 'British Cretaceous Brachiopoda' for list of authors).

Terebrirostra lyra occurs in the Upper Greensand of Horningsham near Warminster, and in various localities in Somerset and Dorset, and in the arenaceous Cenomanian of Devon. It is a rare fossil in the Cenomanian at Cape La Hève, near Havre (France).

We have found several specimens of a variety of this species at Shenley, but they are difficult to extract without breaking off the long beak. Our specimens differ from those figured by Davidson in having finer and more numerous ribs, also in having the long beak more incurved; but as they closely resemble the Havre *T. lyra*, we think it advisable only to consider them as a variety, for which we propose the name of *incurvirostrum*.

Some of our shells have finer ribs than the Havre variety, and are often more globose, but do not differ from it more than the latter does from the Warminster specimens; the Havre shells often show the remarkable incurved beak. Mr. Jukes-Browne states (*op. supra cit.* p. 66) that *Terebrirostra lyra* is rare, but characteristic of the Warminster beds.

Dimensions:—length of large valve=32 millimetres; length of smaller valve=19 mm.; breadth=12 mm.; thickness=7·5 mm. In a smaller globose specimen the length of the large valve=22·5 mm.; length of smaller valve=13 mm.; breadth=8·5 mm.; thickness=9 mm.

TEREBRATELLA MENARDI, Lamarck, var. PTERYGOTOS, nobis. (Pl. XVIII, figs. 3 *a*–3 *c*.)

1819. *Terebratella Menardii*, Lamarck, 'Hist. Nat. des Anim. sans Vert.' vol. vi, pt. i, p. 256. See Davidson, Ann. & Mag. Nat. Hist. ser. 2, vol. v (1850) p. 445 & pl. xiv, fig. 50.
1829. *Terebratula truncata*, J. Sowerby, 'Min. Conch.' vol. vi, p. 71 & pl. dxxxvii, fig. 3.
1834. *Terebratula Menardi*, L. von Buch, 'Ueber Terebrateln' p. 78 & pl. iii, fig. 42.
1839. *Terebratula Menardi*, L. von Buch, Mém. Soc. Géol. France, vol. iii, p. 184 & pl. xvii, fig. 6.
1841. *Terebratula canaliculata*, Fr. A. Rœmer, 'Versteinerungen des Norddeutschen Kreidegebirges' p. 41 & pl. vii, fig. 12.
1847. *Terebratella Menardi*, A. d'Orbigny, 'Pal. Franç. Terr. Crét.' vol. iv, p. 118 & pl. dxvii, figs. 1–15.
1852. *Terebratella Menardi*, Davidson, 'Brit. Cret. Brachiop.' Monogr. Pal. Soc. p. 24 & pl. iii, figs. 34–42.
1868. *Terebratella Menardi*, Schlœnbach, in Benecke's Geogn.-Paläont. Beiträge, vol. i, p. 458 & pl. xxii, fig. 2.
1872. *Terebratella Menardi*, Geinitz, 'Elbthalgebirge' p. 157 & pl. xxxvi, figs. 37–38.
1874. *Terebratella Menardi*, Davidson, 'Brit. Cret. Brachiop.' Suppl. Monogr. Pal. Soc. p. 24 & pl. viii, fig. 14.
1878. *Terebratella Menardi*, Deicke, 'Die Brachiop. der Tourtia von Mülheim' p. 18 & (pl.) fig. 9.
1884. *Terebratella Menardi*, Davidson, 'Brit. Cret. Brachiop.' App. to Suppl. (vol. v) Monogr. Pal. Soc. p. 247 & pl. xviii, fig. 6.

We have found very few specimens of *Terebratella Menardi* var. at Shenley. They differ from the Faringdon shells in being larger and wider; the variety resembles some of the specimens from the Cenomanian of Le Mans (France), but differs from these by the wing-like expansion of the hinge-line. We have not sufficient material to determine whether it should be regarded as a distinct species. Davidson, in his Supplement to the 'British Cretaceous Brachiopoda,' states that the only difference that he can perceive between *T. truncata* and *T. Menardi* is that the Lamarckian species is rather longer and a little more transverse; its ribs are likewise somewhat sharper. Our shells are also remarkable for the great thickening of the front-margin.

Terebratella Menardi occurs in the Cenomanian of Devon and in the Chloritic Marl of Chardstock. In France it is found at several localities, especially at Le Mans in the Cenomanian. In Germany it occurs near Dresden, and at Essen (*T. canaliculata*, Rœmer). It occurs near Tournay (Belgium) in the Tourtia. We consider the Shenley form to be nearer the Tourtia specimens than to those from the Aptian of Faringdon. A single specimen of a variety of *T. Menardi* has been found at Upware; it also occurs at Brickhill.

Dimensions of a shell with thickened front-margin:—length=17 millimetres; breadth=18 mm.; thickness=10·5 mm.

TEREBRATELLA HERCYNICA (Schlœnbach). (Pl. XVIII, figs. 4 *a*–4 *c*.)

1867 [1868]. *Megerleia (?) hercynica*, Schlœnbach, in Benecke's Geogn.-Paläont. Beiträge, vol. i, p. 467 & pl. xxii, figs. 6–7.
1895. *Terebratella (?) hercynica*, Tiessen, 'Die Subhercyne Tourtia u. ihre Brach. &c.' Zeitschr. d. Deutsch. Geol. Gesellsch. vol. xlvii, p. 455.

The specimens figured by Schlœnbach of this species are internal casts from the Tourtia of Quedlinburg, in the Harz, where it appears to be very rare.

The shells that we have obtained from Shenley probably belong to this species, but they are longer in proportion to their width than the Quedlinburg specimens. The shell is longer than wide, of a triangular shape, being widest at the front-margin, tapering towards the beak; both valves are convex. The larger valve has three elevated angular folds, the space between them being deeply furrowed; on each side of the valve are three to five smaller folds, those near the lateral margin of the shell are often obscure; all these folds extend to the extremity of the beak, which is recurved and truncated by a small foramen. The smaller valve has four elevated angular folds; between these the valve is deeply sulcated. On each side of the shell are three or more smaller folds; the folds on both valves extend to the front-margin, and are covered by concentric imbrications. This character was observed by Schlœnbach, who was doubtful whether this form should be referred to the genus *Megerleia* or to *Terebratella*. This species may be a connecting-link between *Terebratella trifida* and *T. oblonga*.

We have obtained very few specimens of this form.

Dimensions:—length = 17 millimetres; breadth = 14 mm.; thickness = 13 mm.

KINGENA LIMA (Defrance).

1828. *Terebratula lima*, Defrance, 'Dict. des Sci. Nat.' vol. liii, p. 156.
1841. *Terebratula pectoralis*, Fr. A. Rœmer, 'Verstein. des Norddeutschen Kreidegebirges' p. 42 & pl. vii, fig. 19.
1847. *Terebratula lima*, A. d'Orbigny, 'Pal. Franç. Terr. Crét.' vol. iv, p. 98 & pl. dxii, figs. 1–5.
1847. *Terebratula spinulosa*, Morris, Ann. & Mag. Nat. Hist. vol. xx, p. 253 & pl. xviii, figs. 6 *a*–6 *c*.
1852. *Kingena lima*, Davidson, 'Brit. Cret. Brachiop.' Monogr. Pal. Soc. p. 42, pl. iv, figs. 15–28 & pl. v, figs. 1–4.
1868. *Megerleia lima*, Schlœnbach, in Benecke's Geogn.-Paläont. Beiträge, vol. i, p. 469 & pl. xxii, fig. 8.
1871. *Terebratula lima*, Quenstedt, 'Brachiopod.' p. 256 & pl. xliv, fig. 55.
1872. *Kingena lima*, Stoliczka, Pal. Indica, 'Cret. Fauna S. India' vol. iv, p. 27 & pl. vii, fig. 13.
1874. *Kingena lima*, Davidson, 'Brit. Cret. Brachiop.' Suppl. Monogr. Pal. Soc. p. 28.
1878. *Megerleia lima*, Deicke, 'Die Brachiop. der Tourtia von Mülheim' p. 20 & (pl.) figs. 12–15.
1900. *Kingena lima*, Jukes-Browne, 'Gault & Upper Greensand of England' [Cret. Rocks of Britain, vol. i] Mem. Geol. Surv. p. 60, &c.

We have not thought it necessary to give references to the various authors who have figured *Kingena lima* from the Chalk. This species has been recorded from the Upper Chalk to the Upper Neocomian, but it can be divided into several subspecies when adult specimens are examined.

The specimens of *Kingena lima* which occur at Shenley show the usual characters of the species—the short recurved beak truncated by a large circular foramen lying close to the umbo, the convexity of the valves, the granulations on the test of the shell. The dorsal valve shows a dark longitudinal line, indicating the presence of a septum. The smaller specimens resemble those from Warminster.

Dimensions of a large specimen:—length = 17 millimetres: breadth = 15 mm.; thickness = 17 mm.

KINGENA ARENOSA (d'Archiac).

1847. *Terebratula arenosa*, d'Archiac, 'Fossiles du Tourtia' Mém. Soc. Géol. France, ser. 2, vol. ii, p. 324 & pl. xxi, figs. 1–3.

We have collected at Shenley several specimens of this species; they vary in the relative convexity of the larger and smaller valves, as stated by Vicomte d'Archiac. The shell-surface shows lines of growth, and the characteristic well-developed granulations. The smaller valve shows the dark line, indicating the median septum.

The largest specimen that we have from Shenley measures in length, 17 millimetres; in breadth, 15 mm.; and in thickness, 10·5 mm.

KINGENA NEWTONII, nobis. (Pl. XVIII, figs. 5 *a*–6 *c*.)

Shell elongated pentagonal, the length exceeding the breadth. The greatest breadth occurs about the middle of the shell, whence it curves towards the nearly straight, wide front-margin; the greatest thickness is about the centre of the shell. The shell-surface is granular, exhibits faint radiating striæ, and shows concentric lines of growth. The larger valve is considerably more convex than the smaller one; it has its maximum thickness about the centre, from which it slopes in all directions towards the margin of the shell; the lateral margin is curved from the greatest width of the valve towards the front-margin, which is nearly straight, only showing a very slight curve; the curve is rounded towards the beak. The beak is short, recurved, and truncated by a moderate-sized foramen; the beak-ridges are concave. The deltidium is wide and shallow, and is in two pieces; this is difficult to observe in many specimens, owing to the friable condition of the shell near the beak. The smaller valve is much less convex than the larger valve; the greatest thickness is near the centre of the shell, from which it is laterally compressed towards the front-margin; the greatest width occurs at about one-third of the length of the shell from the posterior end, whence it curves towards the nearly straight front-margin, giving an irregular pentagonal shape to the valve; the hinge-line is slightly curved. There is a dark line, indicating the presence of a median septum, and showing that the species had a long loop.

The smaller specimen, which is probably the young of the species, has the same irregular pentagonal shape, straight front-margin, shell-structure, and apical angle; but the smaller valve is less laterally depressed, the beak is less recurved, and the deltidium

is more conspicuous. We have observed that in most species of Terebratulidæ the younger shells have the beak generally straighter than it is in the mature specimens.

MEASUREMENTS OF *KINGENA NEWTONII* (IN MILLIMETRES).

	Length.	*Breadth.*	*Thickness.*	*Apical angle.*
A large specimen	26·0	21·5	14·5	95·5°
A smaller specimen ...	21·5	17·5	11·5	95·5°

Deslongchamps and others consider the granular surface as characteristic of the genus *Kingena*; therefore we have placed our shell in that genus, although we have not been able to examine the loop.

This species is easily distinguished from the other Cretaceous *Kingenæ* by its peculiar shape and large size. There are two large species of *Kingena* figured by Stoliczka, in his monograph on the Brachiopoda in the Cretaceous Fauna of Southern India—a circular form, *K. asperulina*, and an ovoid form, *K. shalanurensis*; these cannot be confounded with our species. The *Terebratula pectoralis* of Rœmer is a more regular pentagonal shell, the hinge-line is straighter, and it is not depressed towards the lateral margins.

We have much pleasure in naming this species after Mr. E. T. Newton, F.R.S., who has kindly assisted us in determining the fossils which occur in this deposit.

RHYNCHONELLA GRASIANA, d'Orbigny.

1847. *Rhynchonella Grasiana*, A. d'Orbigny, 'Pal. Franç. Terr. Crét.' vol. iv, p. 38 & pl. ccccxcvii, figs. 7–10.

1854. *Rhynchonella Grasiana*, Davidson, 'Brit. Cret. Brachiop.' Monogr. Pal. Soc. p. 96 & pl. xii, figs. 17–19.

1868. *Rhynchonella Grasana*, Schlœnbach, in Benecke's Geogn.-Paläont. Beiträge, vol. i, p. 496 & pl. xxiii, figs. 8–9.

1872. *Rhynchonella Grasiana*, Pictet, Matér. p. la Paléont. suisse, 'Terr. Crét. Ste. Croix' pt. v, p. 46 & pl. cc, figs. 6–9.

1872. *Rhynchonella Grasiana*, Geinitz, 'Elbthalgebirge' p. 165 & pl. xxxvi, figs. 31–34.

1874. *Rhynchonella Grasiana*, Davidson, 'Brit. Cret. Brachiop.' Suppl. Monogr. Pal. Soc. p. 57.

1878. *Rhynchonella Grasana*, Deicke, 'Brachiop. der Tourtia von Mülheim' p. 26 & (pl.) figs. 20–21.

1900. *Rhynchonella Grasiana*, Jukes-Browne, 'Gault & Upper Greensand of England' Mem. Geol. Surv. p. 65, fig. 43.

The *Rhynchonellæ* found at Shenley which we consider to belong to this species have finer plaits than are exhibited by those which occur at Warminster. Some of the larger specimens seem to connect this species with *Rh. nuciformis*, Sow., the plaits being rounded at the front-margin. Schlœnbach states that *Rh. Grasiana* from the Harz attains the dimensions of 20 millimetres (our biggest specimens measure 18 mm.), and he also remarks that this species is very like *Rh. nuciformis.*

Sowerby figures ('Min. Conch.' pl. dii, fig. 3) a coarse-ribbed shell as *Terebratula nuciformis*, which shows no details whereby the species can be recognized.

Rhynchonella Grasiana occurs at Warminster in the Upper Greensand, and in Dorset, and is common in the arenaceous Cenomanian

of Devon. In France it occurs in the Cenomanian of Havre; the shells there are more finely-ribbed than the English shells. and are nearer to our Shenley specimens. It is found in the Tourtia of Essen (Westphalia) and at Dresden, and in the Upper Gault of Ste. Croix (Switzerland).

RHYNCHONELLA GRASIANA, var. SHENLEYENSIS, nobis. (Pl. XVIII, figs. 9 *a*–9 *c*.)

We will assign to our larger specimens the varietal name of *shenleyensis*; they are wider in proportion to their length. When more specimens have been collected they may have to be separated, and described as a new species.

Dimensions:—length = 13·5 millimetres; breadth = 18·5 mm.; thickness = 10·5 mm.; and the apical angle = 108°.

RHYNCHONELLA LINEOLATA (Phillips).

1829. *Terebratula lineolata*, Phillips, 'Geol. Yorks.' vol. i, p. 173 & pl. ii, fig. 27.
1850. *Terebratula Jugleri*, Geinitz, 'Das Quadersandsteingebirge in Deutschland' p. 208.
1854. *Rhynchonella lineolata*, Davidson, 'Brit. Cret. Brachiop.' Monogr. Pal. Soc. p. 98 & pl. xii, figs. 6–10.
1863. *Rhynchonella lineolata*, W. A. Ooster, 'Brach. Foss. des Alpes Suisses' [Pétrif. remarq. des Alpes suisses] p. 55 & pl. xix, figs. 1–4.
1868. *Rhynchonella* cf. *lineolata*, Schlœnbach, in Benecke's Geogn.-Paläont. Beiträge, vol. i, p. 493 & pl. xxiii, fig. 4.
1872. *Rhynchonella lineolata*, Pictet, Matér. p. la Paléont. suisse, 'Terr. Crét. Ste. Croix' pt. v, p. 48 & pl. cc, fig. 14.
1872. *Rhynchonella lineolata*, Geinitz, 'Elbthalgebirge' p. 167 & pl. xxxvi, fig. 36.
1874. *Rhynchonella lineolata*, Davidson, 'Brit. Cret. Brachiop.' Suppl. Monogr. Pal. Soc. p. 59; var. *Carteri*, *ibid.* p. 60.
1900. *Rhynchonella lineolata*, Jukes-Browne, 'Gault & Upper Greensand of England' Mem. Geol. Surv. p. 314.

Most of the specimens figured in the memoirs quoted above appear to belong to *Rhynchonella lineolata*, var. *Carteri*, Dav. This species is very variable, as may be seen from Davidson's figures; but they all show that the test is ornamented by numerous fine radiating striæ, which near the front of the shell are grouped so as to form plaits at the front-margin, varying in number and in breadth.

Our specimens closely resemble those found in the Greensand of Cambridge, and show the same variations. *Rh. lineolata*, var. *Carteri* occurs in the Greensand of Cambridge, the Red Chalk of Hunstanton (Norfolk), and at Speeton (Yorkshire).

On the Continent this species occurs in the Tourtia of Essen (Westphalia) and at Dresden; also in the Gault of Morteau (Switzerland). Davidson states that he has found it at Drap, near Nice (France), in the Upper Neocomian.

RHYNCHONELLA LINEOLATA (?) var. MIRABILIS, nobis. (Pl. XVIII, figs. 7 *a*–7 *c*.)

We have obtained a remarkable specimen from Shenley, which may be an extreme variety of this species. It differs from any *Rhynchonella* that we have seen.

The shell shows the same striæ as *Rh. lineolata*; its larger valve has a very wide fold in the centre, which shows an angular

indentation at the front-margin, caused by the apex of the central fold of the smaller valve: on each side of the central wide fold is a narrow fold. Beak short, recurved; foramen of a moderate size: beak-ridges well defined, leaving a flattened area between them and the hinge-line; the smaller valve is divided by a fold into three nearly equal parts.

Dimensions:—length = 11 millimetres; breadth = 17 mm.; thickness = 8 mm.

RHYNCHONELLA LEIGHTONENSIS, nobis. (Pl. XVIII, figs. 8 *a*–8 *d*.)

Shell triangular in outline, globose, length and breadth nearly equal, strongly compressed laterally towards the beak; the greatest thickness is about one-third distant from the posterior end; the greatest breadth is at nearly the centre of the shell; each side of the front-margin rises by a gradual curve to about a third of the width of the shell, from which it is nearly straight, forming a central wide fold. The shell is covered by a multitude of fine, well-developed plaits, which extend to the extremities of the beak on both valves. The larger valve has its greatest width near the centre, from which a broad deep central sulcus extends to the front-margin, forming a wide fold; the valve slopes with a slight curve towards the beak, which is short and moderately incurved; the beak ridges are rounded; there is a wide pseudo-area; the foramen is moderately large, and bounded by the deltidial plates. The smaller valve is very globose, having its greatest thickness about the middle; the beak of the smaller valve is broad and tumid, and is compressed towards the posterior part of the lateral margin. There is no elevation corresponding to the deep sulcus of the larger valve by which the centre of the front-margin is widely indented.

Dimensions:—length = 19 millimetres; breadth = 18·5 mm.; thickness = 13·5 mm.; and the apical angle = 95°.

By its peculiar form this species is easily distinguished from other Cretaceous species. We have obtained recently several young specimens of it.

RHYNCHONELLA DIMIDIATA, Sow.

We have several young shells, but have not obtained a sufficient number of adult specimens to investigate properly this species.

RHYNCHONELLA LATISSIMA, Sow.

Some specimens may belong to this species.

RHYNCHONELLA ANTIDICHOTOMA, Buv.

We have found only one perfect *Rhynchonella* which may belong to this species, and a very broad specimen which may be a variety of it.

We have many *Terebratulæ*, often represented by single specimens, which we are unable, for want of material, to assign to their several species. Some of these are probably new forms.

List of Shenley Species of Brachiopoda.	Lower Cretaceous.								Upper Cretaceous.						Foreign Localities. Aptian.		Albian.			Tourtia.					Cenomanian.	
	Hythe.	Potton.	Brickhill.	Upware.	Faringdon.	Surrey.	Speeton.	Lincolnshire.	Gault.	Red Chalk.	Upper Greensand.	Warminster.	Dorset, Somerset.	Arenaceous Cenomanian, Devon.	France.	Switzerland.	Gault, France.	Grandpré (Ardennes).	Switzerland.	Tournay (Belgium).	Westphalia.	Quedlinburg (Harz).	Dresden.	Southern India.	Havre.	Le Mans (Sarthe).
Lingula.																										
Terebratula capillata, d'Archiac				*						*										*	*		*	*		
T. biplicata, Sow., var. *gigantea*, nobis												*								*	*		*	*		
T. bipl. var. *Dutempleana*, d'Orb.									*	*	*						*									
T. depressa, Lam.		*	*	*	*			*								*				*	*	*		*		
T. depr. var. *shenleyensis*, nobis.																										
T. Moutoniana, d'Orb., var.			*	*											*	*				?						
T. Boubei, d'Arch.						?														*						
T. ovata, Sow.												*	*	*											*	
Terebratulina triangularis, Eth.										*	*										*	*	*			
Zeilleria convexiformis, nobis.																										
Magas latestriata, nobis.																										
M. orthiformis (d'Archiac)																				*						
Terebrirostra lyra (Sow.) var. *incurvirostrum*, nobis												*	*	*											*	
Terebratella Menardi, Lam.			*	*									*	*						*	*		*			*
T. Men. var. *pterygotos*, nobis.																										
T. hercynica (Schlœnbach)																						*				
Kingena lima (Defrance)									*	*	*	*								*	*	*		*	*	
K. arenosa (d'Archiac)																				*						
K. Newtonii, nobis.																										
Rhynchonella shenleyensis, nobis.																										
Rh. Grasiana, d'Orb.												*	*	*					*		*	*	*		*	
Rh. lineolata, Phillips							*																			
Rh. lin. var. *Carteri*, Dav.										*	*								*	*			*			
Rh. lin. (?) var. *mirabilis*, nobis.																										
Rh. leightonensis, nobis.																										
Rh. dimidiata, Sow.												*	*	*						*	*	?	*		*	*
Rh. latissima, Sow.				*	*	*														*						
Rh. antidichotoma, Buv.		*	*	*														*	*							

List of Fossils, exclusive of Brachiopoda, from the Band at the top of the Lower Greensand at Shenley Hill.

c. = common.
v.c. = very common.
r. = rare.
v.r. = very rare.

	Lower Cretaceous.								Upper Cretaceous.				
	Hythe.	Potton.	Brickhill.	Upware.	Faringdon.	Surrey.	Speeton.	Lincolnshire.	Gault.	Red Chalk.	Up. Greensand.	Warminster.	White Chalk.
Pisces.													
v.r. *Scapanorhynchus subulatus (?)* Ag.	...	...	...	...	...	...	...	...	...	...	?	?	?
Cephalopoda.													
v.r. *Ammonites* sp. (see text, p. 244).													
v.r. *Belemnites* sp. (see text, p. 244).													
Gasteropoda.													
v.r. *Aporrhais* sp.													
r. *Natica* sp.													
v.r. *Trochus* sp.													
r. *Turbo* sp.													
Lamellibranchiata.													
c. *Avicula* sp. indet.													
r. *Cyprina* sp.													
c. *Exogyra* (small sp.).													
c. *Janira quinquecostata*, Sow.	*	...	...	...	...	*	...	...	*	*	*	*	*
r. *Lima* sp. indet. (but cf. *faringdonensis*, Sharp)	...	...	*	...	*								
r. —— sp. (resembling *globosa*, Sow., of the Lower Chalk)	...	...	...	...	...	...	...	...	...	...	...	?	?
r. *Modiola* sp. (cf. *ligeriensis*, D'Orb.)	1	...	...	...	...	...	...	...	...	...	*	*	?
c. *Ostrea* sp.													
r. *Pecten (Camponectes) cinctus ?* Sow.	...	...	...	...	...	...	*	*					
v.c. —— *(Syncyclonema) orbicularis*, Sow.	*	...	...	...	...	*	*	*	*	*	*	*	*
c. —— *(Chlamys) Robinaldinus*, D'Orb.	*	*	...	?	*	*[2]	...	...	...	...	*	*	*
r. —— sp. (cf. *subacutus*, Lam., & cf. *urgonensis*, De Lor.)	...	...	...	...	...	...	...	...	...	...	...	?	
r. —— sp.													
r. —— sp.													
v.c. *Septifer lineatus*, Sow.	*	...	...	...	*	...	...	...	...	...	*	...	*
v.r. *Spondylus Rœmeri (?)* Desh.	1	...	*										
[For the Brachiopoda see preceding List.]													
Echinodermata.													
v.r. *Cardiaster latissimus*, Ag.	...	...	...	...	...	...	...	...	...	...	*	...	?
—— sp. (not *C. Benstedi*).													
v.r. *Catopygus columbarius*, Lam.	...	...	...	...	...	...	...	...	...	...	...	*	*
c. *Cidaris* (spines like *C. Bowerbankii*)													
v.r. *Echinobrissus lacunosus*, Goldf.	...	...	...	...	...	...	...	...	...	...	...	*	
v.r. *Pyrina lævis*, Ag.	...	...	...	...	...	...	...	...	...	...	...	*	
Crustacea.													
v.r. *Plagiophthalmus (Prosopon)* sp.													
Annelida.													
c. *Serpula* indet.													

[1] '*Perna*-Bed' of Atherfield.

[2] Atherfield Clay.

Summary.

1. This paper describes a newly-discovered fossiliferous band at the top of the Lower Greensand, overlain by the Gault, in the sand-pits at Shenley Hill, near Leighton Buzzard (Bedfordshire).

2. The fossils of this band present a facies different from that of any previously-known fossiliferous horizon of the Lower Greensand, and show closer affinities with the fauna of the Upper Greensand than have hitherto been recognized in any deposit below the Gault. The brachiopods are closely allied to those contained in the Tourtia of Belgium.

3. The fossiliferous bed is rather sharply marked off from the underlying unfossiliferous 'silver-sands,' but is still more sharply marked off from the overlying Gault. Stratigraphically it forms part of the Lower Greensand, and cannot, without violence to the accepted classification of the deposits, be considered to belong to the Gault.

4. The fossils constitute a newer Lower Cretaceous fauna than has yet been recognized as such in England. Several species, hitherto supposed to be confined to the Selbornian, are now shown to have been in existence before the deposition of the Gault.

5. The lithological characters of the bed indicate a sea-bottom of moderate depth, swept by powerful currents; and the conditions were thus similar to those which persisted in the neighbourhood throughout Lower-Greensand times. The overlying Gault shows a change to more tranquil waters, probably of greater depth.

6. The brachiopoda, which are the most abundant fossils, are fully described, and representative specimens figured. These include several species or well-marked varieties regarded as new, together with others not hitherto recorded in England.

EXPLANATION OF PLATES XVI–XVIII.

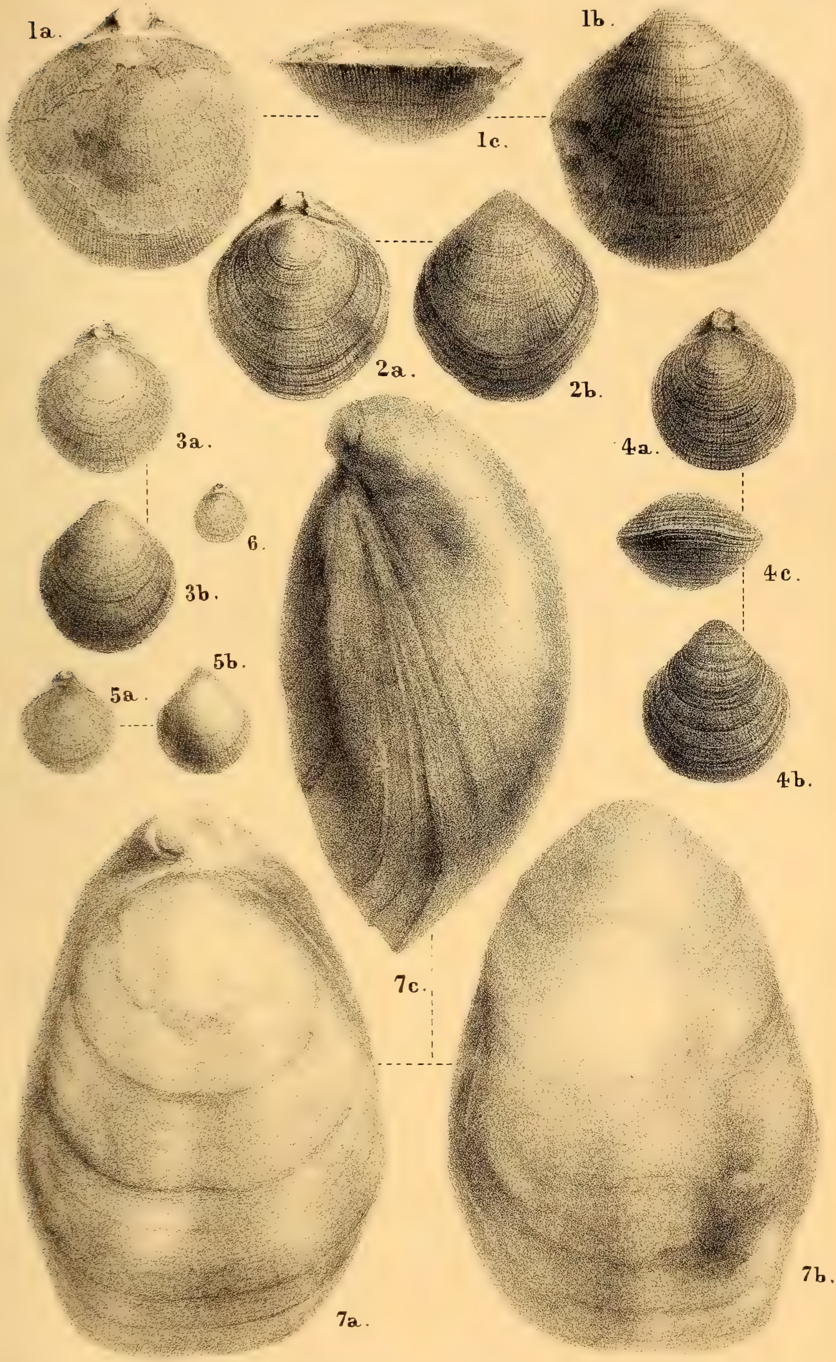
[All the specimens are figured of the natural size, except where otherwise stated. They have been presented by the Authors to the Museum of the Geological Society of London.]

Plate XVI.

Figs. 1 *a*, 1 *b*, & 1 *c*. *Terebratula capillata*, d'Archiac. This Shenley specimen agrees with d'Archiac's type.
2 *a* & 2 *b*. *Terebratula capillata*, d'Archiac. A specimen with a wide fold.
3 *a* & 3 *b*. *Terebratula capillata*, d'Archiac. A smaller specimen, with a wide fold.
4 *a*, 4 *b*, & 4 *c*. *Terebratula capillata*, d'Archiac. An ovoid globose specimen.
5 *a* & 5 *b*. *Terebratula capillata*, d'Archiac. A young specimen.
Fig. 6. *Terebratula capillata*, d'Archiac. A very young specimen.
Figs. 7 *a*, 7 *b*, & 7 *c*. *Terebratula biplicata*, var. *gigantea*, nobis. This is the largest specimen that we have obtained from Shenley.

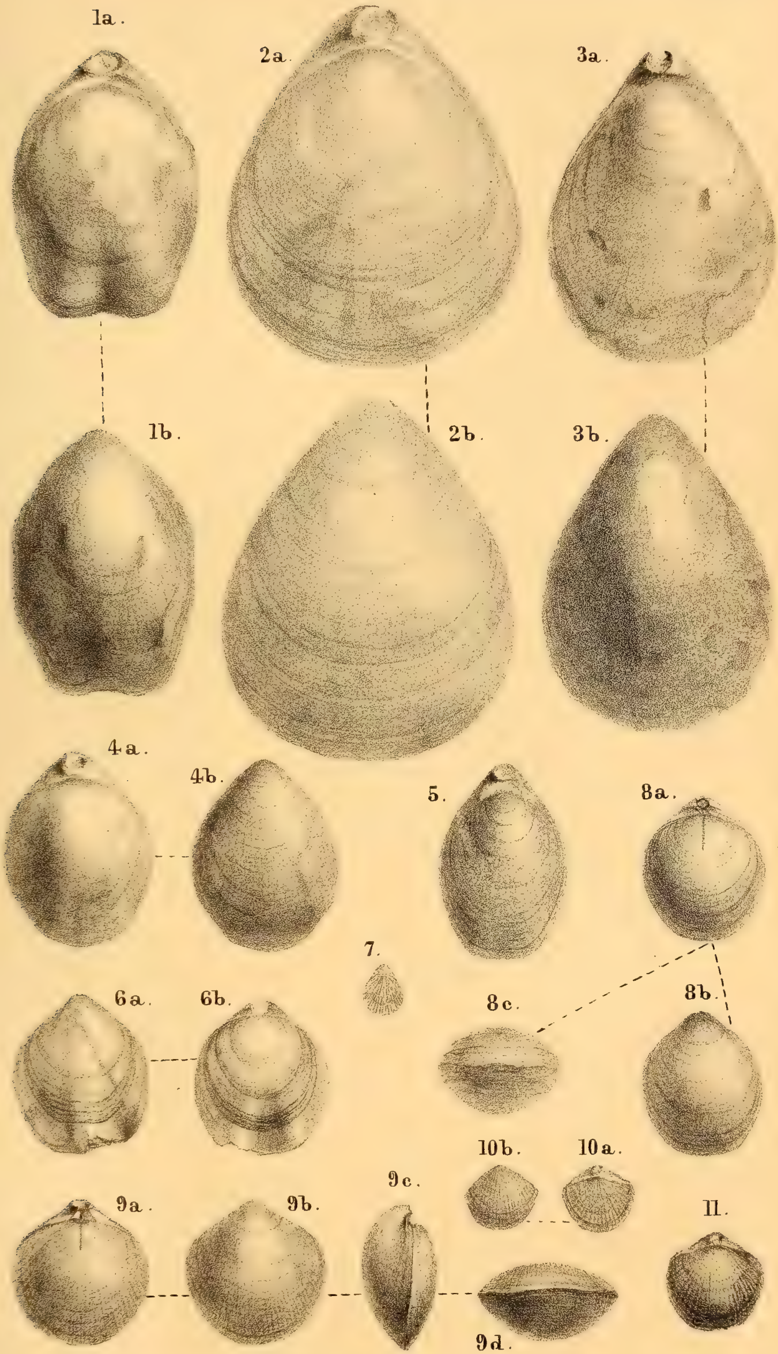
Plate XVII.

Figs. 1 *a* & 1 *b*. *Terebratula biplicata*, var. *Dutempleana*, d'Orb.
2 *a* & 2 *b*. *Terebratula depressa*, var. *shenleyensis*, nobis.
3 *a* & 3 *b*. *Terebratula depressa*, var. *shenleyensis*. A smaller specimen.
4 *a* & 4 *b*. *Terebratula Moutoniana*, d'Orbigny, var.



F. H. Michael del. et lith. Mintern Bros. imp.

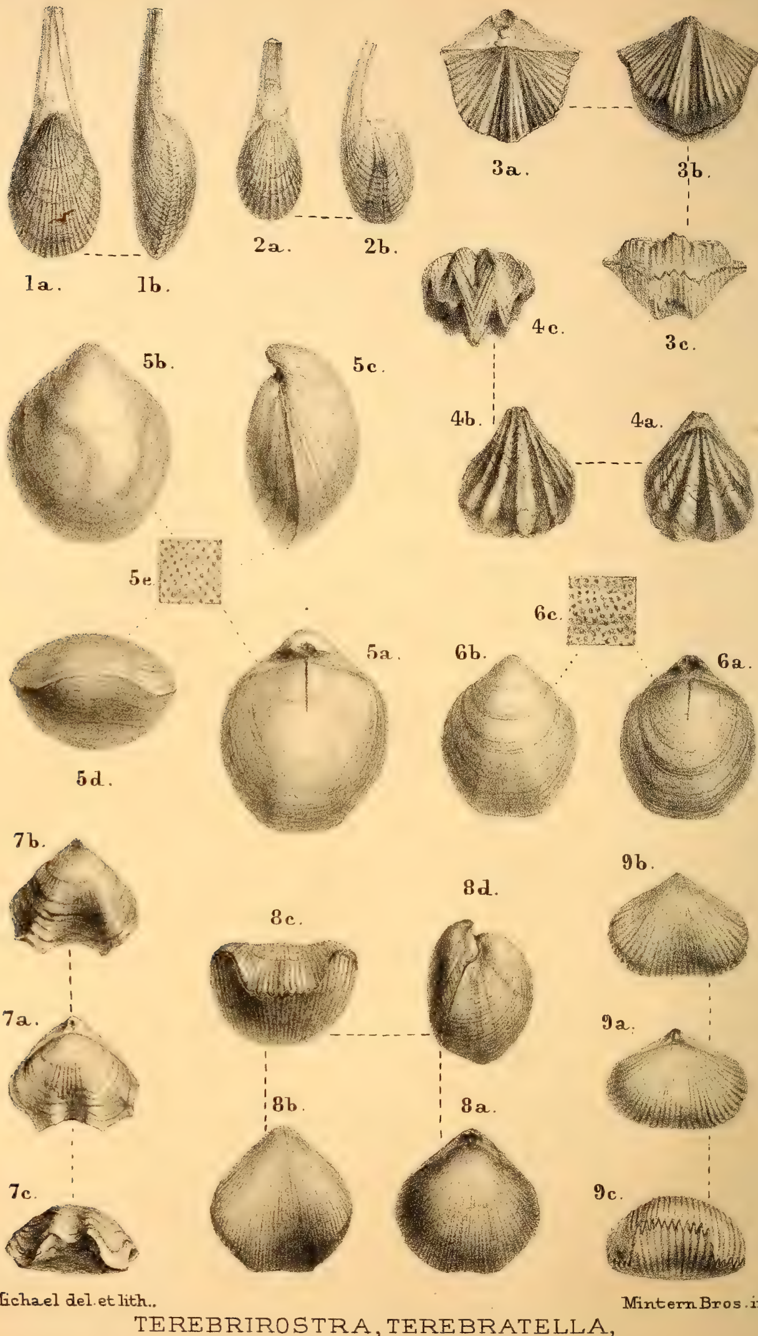
TERÉBRATULA CAPILLATA
& T. BIPLICATA VAR. GIGANTEA, NOV.



F. H. Michael del. et lith.

Mintern Bros. imp.

TEREBRATULA, MAGAS, ETC.



F. H. Michael del. et lith.

Mintern Bros. imp.

TEREBRIROSTRA, TEREBRATELLA, KINGENA, & RHYNCHONELLA.

Fig. 5. *Terebratula Boubei*, d'Archiac.
Figs. 6 *a* & 6 *b*. *Terebratula ovata*, Sowerby.
Fig. 7. *Terebratulina triangularis*, Etheridge.
Figs. 8 *a*, 8 *b*, & 8 *c*. *Zeilleria convexiformis*, nobis.
9 *a*, 9 *b*, 9 *c*, & 9 *d*. *Magas (?) latestriata*, nobis.
10 *a* & 10 *b*. *Magas orthiformis* (d'Archiac).
Fig. 11. *Magas orthiformis*. A large round variety.

Plate XVIII.

Figs. 1 *a* & 1 *b*. *Terebrirostra lyra*, var. *incurvirostrum*, nobis.
2 *a* & 2 *b*. *Terebrirostra lyra*, var. *incurvirostrum*, nobis. A smaller, curved specimen.
3 *a*, 3 *b*, & 3 *c*. *Terebratella Menardi*, Lamarck, var. *pterygotos*, nobis.
4 *a*, 4 *b*, & 4 *c*. *Terebratella hercynica* (Schlœnbach).
5 *a*, 5 *b*, 5 *c*, & 5 *d*. *Kingena Newtonii*, nobis. Fig. 5 *e* is an enlargement of a portion of the shell, to show its granular surface.
6 *a* & 6 *b*. *Kingena Newtonii*, nobis. Younger specimens. Fig. 6 *c* (see explanation of fig. 5 *e*).
7 *a*, 7 *b*, & 7 *c*. *Rhynchonella lineata (?)* var. *mirabilis*, nobis.
8 *a*, 8 *b*, 8 *c*, & 8 *d*. *Rhynchonella leightonensis*, nobis.
9 *a*, 9 *b*, & 9 *c*. *Rhynchonella Grasiana*, var. *shenleyensis*, nobis.

Discussion.

Prof. Seeley said that he had had the advantage of seeing Mr. Walker's collection of fossils from this interesting locality. It reminded him, in its general affinities, of the Faringdon fauna as described by R. A. C. Godwin-Austen, among which were some fossils previously known only from higher horizons. In this deposit the presence of *Cardiaster* and *Catopygus*, of *Terebrirostra lyra*, *Terebratula capillata*, *T. biplicata*, and many other species, suggested the horizon of the Upper Greensand; though the brachiopods differed as varieties from those hitherto known. But these fossils were associated with some Lower-Greensand types, such as *Terebratella Menardi*, and those also differed from the forms found in the Hythe Beds of Kent. There were affinities which linked the fauna with the other areas north of the Weald, rather than with those to the south; but the cause of the mixture of faunas was not at present explained. He would have preferred to limit the term Lower Greensand to the southern deposit between the Weald-Clay and the Gault, and to use Godwin-Austen's term Neocomian for these northern beds, which extend from the Gault to a geological horizon much older than the Weald. This fauna was a distinct addition to the palæontology of a rock which includes diverse assemblages of fossils in its principal outcrops.

Mr. Lamplugh, on his own behalf and on that of his absent colleague, thanked the Fellows for the reception accorded to their paper, and Prof. Seeley for his kind appreciation of the work. He thought that the term Neocomian should not be applied in the broad sense desired by Prof. Seeley, as it was restricted in France to one stage only of the Lower Cretaceous.

20. *The* Sedimentary Deposits *of* Southern Rhodesia.

By Arthur J. C. Molyneux, Esq., F.G.S. With Appendices by Dr. A. Smith Woodward, F.R.S., F.L.S., F.G.S., Dr. Wheelton Hind, B.S., F.R.C.S., F.G.S., and E. A. Newell Arber, Esq., M.A., F.G.S.

(Read January 21st, 1903.)

[Plates XIX & XX.]

Contents.

I. Introduction.

Southern Rhodesia lies between the Rivers Zambesi and Limpopo where they approach nearest to each other, a distance of 400 miles. Its greatest breadth is from the Victoria Falls on the west to the 33rd degree of longitude on the east, a distance of 450 miles, and it has an area of 192,000 square miles. The major portion of this extent is occupied by grey granite and gneiss, and by the metamorphic schists and slates that contain the numerous quartz-veins extensively worked by an ancient people, and now being again opened up for the extraction of gold and copper. The area over which these rocks occur measures 140,000 square miles, the remaining portion being taken up by sandstones and volcanic rocks.

Whatever may have been the original condition of the slates and schists of the gold-belts, igneous or sedimentary, they are now so indurated and cleaved by lateral pressure that their present state only is recognized in this paper, and they are referred to as schists or metamorphic rocks, or when associated with the granites and gneisses, are included in the term Archæan rocks. The slates lie at an almost vertical angle, and the lapse of time and vast amount of erosion that took place before they were covered by the deposition of the sedimentary beds now to be described (which, in striking contrast, lie at low angles or horizontally) give rise to the 'great unconformity' of Rhodesian geology.

The Archæan rocks of Rhodesia have frequently formed the subject of scientific communications; but, so far as I am aware, no notices have appeared on the sedimentary deposits of the country, and it is the object of this paper to set forth briefly the result of observations made in travelling over the area occupied by these rocks.

Their extent is so considerable that the close examination of them must prove an arduous undertaking, and necessitate a large staff of observers as well as a great expenditure of time. In traversing the country, however, I have noted, as carefully as possible, such facts as came under my observation, and have obtained sufficient information to serve as an introduction to the geology of this portion of Southern Rhodesia, which is especially interesting at this time, as the sedimentary rocks are associated with large areas of workable coal, and also because of the recent discovery of certain fossil remains, which form the subject of appendices to the present paper.

While the country along the watershed has been correctly surveyed and mapped, and is thoroughly well known owing to the mining industry now being conducted there, the area of the sedimentary beds is almost unexplored, and the maps of Rhodesia to the north and south of the gold-belts are made up from sketches furnished by hunters, for, with the exception of the coal-outcrops, prospectors and miners find no inducements to visit this region.

The best method of showing the general order of stratification of these deposits is to draw attention to a series of sections made in travelling over these areas. The main section forms a complete illustration of the country from the Zambesi River on the north, through Bulawayo and the central plateau, to near the Limpopo River on the south, a distance of over 400 miles. Others illustrate the arrangement of strata in the northern districts, parallel to the main section, and also in the south, and illustrate the contact of the sediments with the schists and crystalline rocks, which form the basement-system of this portion of South Africa.

By these sections the line of the 'great unconformity' is intersected on the north at places 100 miles apart, and again on the south-west; and it is thus possible to arrive at some definite and important conclusions regarding the general arrangement, order of deposition, and thickness of the sediments lying in the low country which now nearly surrounds the elevated plateau of Southern Rhodesia—the lowlands towards the eastern coast excepted.

II. The Northern Sediments. (Pl. XIX—sections.)

[Geological sketch-map on p. 276.]

Main Section (Pl. XIX, fig. 1).—This is drawn along the main road from Bulawayo through Shiloh to the Sengwe Coalfield, a direction almost due north. The town of Bulawayo lies at an altitude of 4469 feet, on the metamorphic rocks which form the auriferous area known as the Bulawayo gold-belt. On taking the northern road a strip of very fine sandstone is seen to begin about a mile beyond the Umgusa River, 6 miles distant, and occupies a ridge some 4 miles wide. This is a westerly extension of the Thaba 'Sinduna Series, which forms the conspicuous flat-topped hill lying about 12 miles to the north-east of the town, overlapping the schists.

This sandstone constitutes the highest-remaining horizon of the Mesozoic formations in Rhodesia, and east of the road there is

abundant evidence, in the form of horizontal sheets of vesicular lava, in the volcanic neck, known as Umfazi 'Miti, and in the noticeable induration of the rocks, to show that here was the centre of the volcanic disturbance which has had such a hardening effect on the beds of Thaba 'Sinduna. These flat basalt-sheets continue as far as Shiloh, where they are about 100 feet thick, and break off in sloping hillsides. They lie upon fine red sandstone, which forms the bed of the Umgusa Valley, and across that flat to the west similar basalt-sheets form other flat-topped ridges and outlying hills.

Some 20 miles to the north the volcanic rocks die out, and the country is then gently undulating and composed of fine red sandstone. At the Bembesi the schists of the gold-belt, named after that river, crop up and are exposed for a width of 4 miles. Sandstones again come in, and continue to the Bubi River, where basalts (interbedded with fine red sandstone) are once more to be seen, the underlying sandstone-bed being indurated and much cracked, and the fissures infilled with white silica, while the overlying sandstone shows no alteration. Some of the lava here is highly vesicular, and is studded with amgydales. On both the Bubi-River and Gwampa slopes of the watershed the upper sandstone has been removed, and basalt forms the capping of the flat-topped foot-hills.

The Shangani River has denuded a valley some 1500 feet lower than the altitude of Bulawayo, and runs in a plain of alluvium from half a mile to 2 miles wide. From that river onward the predominant rocks are still red and yellow sandstone, covered with open forest, until, at 170 miles from Bulawayo, the undulating country stops short with an abrupt descent of 400 or 500 feet to the level of the Matobola Plains. This sudden drop is caused by an escarpment of coarse red, incoherent sandstone, containing subangular pebbles of jasper, banded ironstone, quartz, etc., which either occur in irregular layers or scattered singly or in groups throughout the grit.

This escarpment begins many miles away to the south-west. It is even a feature on the main road from Bulawayo to the Wankies Coalfield, 60 miles distant, and runs in a broken line north-eastward, making the Gololo, Domwe, and Guramina ranges, then continuing round the headwaters of the Sesami and Bumé Rivers (60 miles to the east: see Pl. XIX, fig. 2), whence it is noticeable in broken bluffs away to the north-east near Gorodema's Kraals, until it seems to merge with the Mafungabusi Mountains.

The breaks in the precipitous cliffs are where rivers, such as the Gunyanka, Senka, Sengwe, Bumé, and Sesami, flowing from the southern plateau have eroded gently-sloping valleys in the friable rocks; but these interruptions make the general line more noticeable, and give a bolder appearance to the perspective of receding bluffs. The escarpment is made more prominent by the strip of flat country, from 5 to 14 miles wide, known as the Matobola Plains, which extend along the whole course of the base of the range. Until this escarpment is reached, the sandstones (where cropping out in an unweathered state) exhibit no dip, but in the cliffs the beds first show a slight inclination to the south.

From the extensive views that can be gained from any part of the Great Escarpment it can be seen that across the Matobola Valley rises another line of broken hills, generally sloping, and only occasionally showing a precipitous outline when viewed from the south. This is the Mlambo and Sijarira range, and its axis follows the same north-easterly direction, hence the escarpment, plains, and hills are all parallel.

Descending from the escarpment, and turning towards these hills, the section crosses the plains, which are black in the winter season, not only because of the natural darkness of the soil, but from the ashes of grass and weeds burnt by the fires which yearly sweep across their huge expanse. The plains undulate gently, with a general northerly slope, and thus the deep erosion of the river and the general upward tilt of the rocks being in the same direction, the underlying strata are one by one brought to view.

The traverse thus comes to the lower series (Lower Matobola Beds) of black shales and clays, with workable seams of coal, which are of great extent and are referred to later (p. 281). The two series of fine carbonaceous beds are separated by a deposit of micaceous ferruginous sandstone, with grits and conglomerates, forming a continuous and low ridge for many miles: this group (Bussé Series) yields the fish-remains described in Appendix I, p. 285.

The coal-bearing beds lie upon a group of derived rocks, generally of a coarse sandy composition, showing much current-bedding, but with occasional patches of shales and sandy clays, altered sometimes into quartzites.

In continuation of the section north from the coalfields the strata become more highly tilted, until they break off at the summit of Gongoriba and Chongola Mountains. Quartzites then come in, and form the southern and northern slopes of the Sijarira Plateau or Range. The centre of that tableland resumes the normal condition of loosely-coherent sandstones, with horizontal stratification, but the north-western edge shows the rocks to have again become indurated. Here they are also folded and fissured, and seem to be near the axis of an anticline, but only a few folds now remain visible at the top of the precipitous mountain.

From this point there is a quick descent of 1400 feet in a few miles, and the steep northern slope of this mountain-range, extending from the Lubu Gorge (see Pl. XIX, fig. 3) to the Sengwe River, about 60 miles, is a prominent feature of this district, for only low broken country now intervenes between it and the Zambesi River, which it overlooks 35 miles away. On descending the mountain the loose, irregularly-bedded sandstones are seen to be horizontal, and there is no sign of the disturbance which folded the rocks at the apex of the range.

From the base of the range the coarse current-bedded sandstones continue until the Zambesi is reached, with local and intermittent zones of quartzites or indurated finer sediments. The thickness of the series, measured downward from the base of the coal-bearing beds to the level of the Zambesi Valley, must be at least 2000 feet.

Pl. XIX, fig. 2.—This section is taken along the road from the Sinanombi gold-field to the Inyoga country, along a line nearly parallel to, and 60 miles east of, that of the main section. The fragmental beds commence at the Djombi River with a surface-width of 2000 feet of angular gravel, composed of quartz, jasper, banded ironstone, and slate with numerous agates. These constituents, being peculiar to the gold-belt, are doubtless the débris of an overlap by the basement-conglomerate of the Mesozoic deposits.

At the Ifafa River, while the banks are of red ripple-marked sandstone, gneiss appears to form the bed of the water-course.

From this river to beyond the headwaters of the Sengwe, the formation is of fine red sandstone, and is followed by an exposed sheet of basalt with amygdales of agate, etc. This is most probably a continuation of a sheet of the same rock which occurs on the Bombasi River, 15 miles away to the south-west, but it is there interbedded among sandstones. This sheet it is proposed to indicate provisionally as the Sikonyaula Basalt. Its length has not been traced, but the width is 24 miles, being abruptly cut off by the continuation of the Great Escarpment, of which it here forms the capping, 200 feet thick. It rests upon fine red sandstone, and at the junction of the two beds there is a spring of water, near which are several silicified trees. The sandstone here dips southward at an angle of 5°.

All the way along the foot of this escarpment run the flat Matobola Plains (5 to 14 miles wide) which extend from Pashu's Kraal to and beyond the Bumé River, a distance of over 100 miles. They are composed of the finer sedimentary beds, such as clays, slates, and even thin coals, comprising a distinct series of deposits, which may be known as the Upper Matobola Beds. The disintegration of these deposits has resulted in a black earth which, during the rains of summer, is converted into a thick sticky mud; but, on drying in the winter, it bakes hard, and cracks into a network of fissures. It grows a rich pasture, and the open plains were once the home of herds of buffalo. These were decimated by the rinderpest in 1896, and only a few head are now supposed to exist in this region.

Pl. XIX, fig. 3.—Going westward some 25 miles from the Sengwe Coalfield, or from the line of the main section, over a ridge of quartzites and incoherent sandstones, the native footpath comes to another wide and open flat, in which occur the finer beds of the Lubu Coalfield. It is probable that this flat area is connected with the Matobola Plains already described, which extend to Pashu's Kraal on the south-west. This basin is drained by the Lubu River, which runs through a range of hills to the north-west, linking the Sijarira Mountains to the Namkanya Mountains. In this locality the range is still formed of coarse sedimentary beds, but the 300-foot deep river-gorge shows that these rest upon gneiss and pegmatite. The section figured was taken along the footpath that runs from the coal-exposure in the Lubu River, passing the Native Commissioner's camp, and over the low spurs at the western end of

the Sijarira Range, to the Zambesi River at Binga's Kraal, a distance of about 30 miles.

Among the shales revealed by the erosion of the Lubu River while crossing the flat, several seams of workable coal of excellent quality may be seen. At one especially noticeable point these deposits are tilted against a prominent reef of quartz some 30 feet high, and extending in a north-easterly direction for 200 yards. Here the dip of the beds is 15° to the south-east. Proceeding farther down the river, this high angle gives way to a general dip of 5° southward, and one mile still farther down the river-sandstones come in and continue as the surface-rock as far as the Sijarira footpath. The river then runs into its deep gorge, which has a circuitous length of about 9 miles. The section of the rocks revealed in the walls of this chasm gives the following approximate measurements:—

	Thickness in feet.
Current-bedded sandstones, with local indurations	100
Grey sandstones, with irregular pebble-beds	50
Red shales	50
Coarse red sandstones	20
Red shales	50
Angular grey conglomerate, compact, with pyrites	10
Gneiss	Basement.

The dip of these beds is still consistently southward, but there are local disturbances with axes following a general easterly-and-westerly direction. These are the result of earth-movements, and show for their central cores dykes of a crush-breccia, made up of angular blocks of red or grey quartzite cemented together by white silica. Where these dykes have been cut through by the river, the cementing silica takes on the chalcedonic form, showing distinct banding as in agates.

Ascending from the river-gorge, the footpath towards the Zambesi goes below the high western end of the Sijarira Range, and the denudation of the sedimentary strata there reveals a belt, about 6 miles wide, of the basement-gneiss and granites, north of which the sandstones again occur and extend to the Zambesi. The contact with the crystalline rocks in this direction is hidden under débris or wash from the hill. But the sedimentary deposits may be seen farther on to consist of false-bedded and coarse sandstones, the current-bedding occurring very frequently. The last exposure of these rocks on the south side of the Zambesi River is where they form a far-stretching bluff or escarpment about 200 feet high, taking a north-easterly and south-westerly direction, and forming the wall of the river-valley for many miles. At Binga's Kraal the alluvial plain is some 5 miles wide, and the river, which here is about 300 yards in breadth and a gentle, navigable stream, takes a winding course across the valley between the southern and opposite hills.

The exposure of crystalline rocks under the end of the Sijarira Range takes also a south-westerly direction towards, and disappears under, the high Namkanya Mountains, a range conspicuous from the

table-like appearance of its summits, characteristic of the horizontal sediments, noticeable also in the portions of the Great Escarpment extending through the Gololo, Domwe, and other mountains, and reaching as far as the Mafungabusi Hills which have been described by Mr. C. J. Alford. The crystalline area comprises quartz-veins (in which occur large segregations of mica), hornblendic schist, pink felspar with quartz-crystals, and veins of pink and white pegmatite. Where the gneiss is seen, it is crushed and folded along an axis directed to the north-east. Finely-crystalline granite is here absent, and the crystals of felspar and quartz that do occur fall apart very readily, so that the surface of the hills is covered with a débris of sharp, angular, and loose pieces of rock.

I have also traversed the country from the foot of the Namkanya Mountains to the Zambesi Valley, but do not here give any illustrative sections. These mountains are composed of almost horizontal beds of coarse sediments with conglomerates, at the foot of which shales crop out. Here is another flat basin, the Sebungu Coalfield, drained by the lower portion of the Lubu River, which now takes the name of Sebungu, and in the bed of the river are numerous outcrops of coal-seams, also dipping southward and south-westward at an angle of 5°. The outcrop of these seams is very striking, for as their gently-inclined edges are broken off by the river, the intervening spaces are filled with bright yellow sand, and this succession of black outcrops and bright alluvium extends for nearly a mile down the stream. On the northern side of this basin, near Panjula's Kraal, the strata are tilted at a higher angle against a ridge of quartzites, which cut off the further extent of finer sediments to the north, and seemingly belong to the underlying group of Sijarira Quartzites. In the Sebungu Coalfield the area of exposed coal-bearing beds is over 100 square miles. From this point westward in the direction of the Zambesi, red sandstones and quartzites occur.

Pl. XIX, fig. 4.—The overlap of the sedimentary strata to the south-west of Rhodesia is first noticed at the Macloutsie River, on the railway, near mile 1200 (or 160 miles from Bulawayo). They there lie upon a gneissose granite showing cleavage-planes inclined at a high angle to the south, and cap the hill lying immediately beyond the river. Thence they extend to mile 1194, where gneiss again crops out, but immediately disappears under a basin of very fine sedimentary beds at the Sisi Siding. Another ridge of schist, with greenstone and quartz-dykes, occurs at mile 1189, where a third area of sandstones and shales begins and extends for $6\frac{1}{2}$ miles. Another small basin of sediments occurs at mile 1179. These narrow areas of derived beds lie in hollows in the metamorphic rocks, and are tongues stretching out from the great expanse of red sandstones and sedimentary deposits on the west.

Between mile 1179 and mile 1146 crystalline and metamorphic rocks are continuous, when red sandstone crops out near Dikabi and

extends along the railway to below Palapye Station: here flagstones and limestones are seen in the river-banks.

At Mapani Pan, 8 miles to the south, a small seam of coal was discovered, during the sinking of a well for water, in the coarse white sandstones and grits. This led to a borehole being put down to a depth of 778 feet. No other coal was found, but the formation is carbonaceous, and yielded the following section:—

	Thickness in feet.
Sandstones and grits	113
Sandy shales	415
Black shales	211
Olive-coloured mudstone ...	31
Conglomerate	8
Red granite	Basement.

From this point the sediments extend westward in the direction of the Great Desert, and characteristic flat-topped hills occur at Suanin and Serui. The large hill at the back of the Palapye native settlement (Chopong) is formed of higher strata of white quartzite, overlying loose-grained and current-bedded sandstones dipping 5° northward. From the foot of these hills the country is flat towards the north, but at a distance of a few miles a prominent range, known as the Palapye Koppies, stands up at a height of 300 feet. These are the remnant of a denuded intrusive dyke, extending some 6 miles south-westward, which has crushed and folded the softer sediments, and is the cause of the gradual induration of the shales and sandstones, that becomes more noticeable as one proceeds from the station to these hills.

From Palapye the sandstones extend to the flat-topped Selika Hills, and range across the Limpopo into the Transvaal.

If we prolonged the southern portion of the main section across the territory from the Zambesi, we should notice that no sediments are met with, until Umsingwane Drift on the Pioneer Road is crossed. This is 150 miles from the watershed, and whereas sandstones commence immediately to the north of the highest part of the country, the southern slopes are completely bereft of them until this point is reached.

These beds are seen at first to be fine-grained and felspathic, grey, red, and purplish in colour, and they form a small hill east of Umsingwane Drift. The area is not more than a square mile, and river-erosion has eaten considerably into the outlier, and replaced it with alluvium. On the east the sediments thin out against the metamorphic rocks, and on the south disappear under the belt of volcanic ejectamenta which, commencing near Macloutsie, extends eastward across the country to beyond the Bubu River, a distance of at least 200 miles. There are also areas of these rocks far away towards Sabi, the breadth of the belt being from 20 to 30 miles. Fort Tuli, the military base of the forces that entered Mashonaland in 1889, is in the central area of this volcanic region: indeed the fort

is situated upon the denuded scoriæ and lava-flows of an extinct crater, and in the trenches these ejectamenta can be easily studied.

This area of past volcanic action may therefore well be known as the Tuli Lavas. In the traverse described, which crosses the scoriaceous deposits 40 miles to the east of Tuli, these volcanic rocks form a belt 30 miles wide. On the southern boundary they gradually die out against a series of parallel ridges of fine sandstone, which have been crushed and minutely cross-fissured, the reticuate fissures being now infilled with silica. The rock is therefore extremely hard, and has weathered in rugged parallel ranges, all following a general north-easterly direction.

It can be seen that this crushing and shearing has been caused by intrusive dykes. In the Chilichukwe River, near an old fortified hill 8 miles east of the Umsingwane River, the gradually-extending influence of a dyke is very noticeable. The rock is there a fine white felspathic sandstone, with few main fissures, but cracks begin 30 feet away, and become more frequent until they are only an inch or less apart. The sandstone then becomes altered to quartzite, and the dyke breaks in. It shows tabular jointing at the sides, where it resembles a stack of tiles on edge, $1\frac{1}{2}$ to 2 inches wide; farther in the joints are 6 inches apart, while the centre is irregularly jointed—the total breadth being 12 feet.

This alteration by contact-metamorphism is noted as a cause for the induration of some of the long ridges of veined sandstone which extend across this portion of the Tuli district, while others are due to cracking along faults and may be almost called crush-breccia. Where this induration occurs, the hardened rock has resisted decay, forming ridges and lines of hills rising out of the generally level country of the Tuli district, such as the bluff at Massabi's on the Limpopo River, and the Samkoto Cliff on the Umsingwane River. Hence the provisional term of Samkoto Series is applied to the soft sandstones and the indurated veined quartzites of this locality.

South of Samkoto Cliff, they lie unconformably on garnetiferous quartzites, foliated schists, hornblendic gneiss, etc., highly inclined to the north—and farther south these schists merge into gneiss and granite, containing veins of pegmatite, and quartz with mica-crystals several inches across.

Lying unconformably in a basin in the Samkoto Series are the generally-horizontal beds and workable seams forming the Umsingwane Coalfield. These softer sediments are capped by conglomerate, and extend from the Umsingwane River to the Singwisi, 5 miles away, where there are many intrusions of dolerite, which have altered the coal-seams at that end of the basin into a semi-anthracite. The coal-bearing beds also crop out in the Limpopo Valley, where they rest upon the tilted metamorphic rocks. The Tuli Lavas are later than, and overlie, the coal-bearing beds in this district.

The southern sediments, except for a calamite found in the Umsingwane Coalfield, have so far yielded no fossils, but in

accordance with their physical features may be classified as follows:—

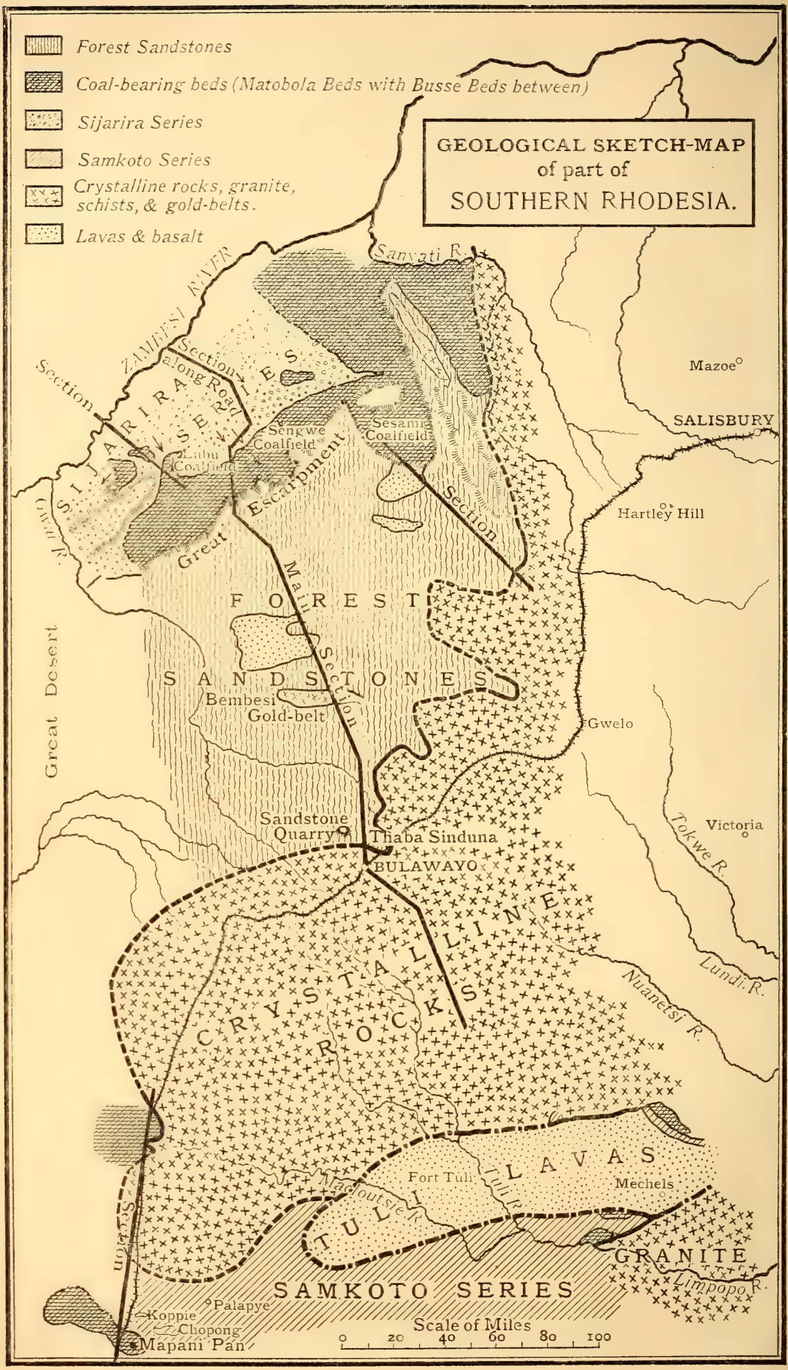
Tuli Lavas.
Coal-bearing beds
(Unconformity).
Samkoto or veined sandstones
(Unconformity).
Metamorphic rocks.
Gneiss and granite.

III. The Physical Features and Grouping of the Rocks.

From the sections described and figured and information acquired by other means, it now becomes possible to sketch in the boundary between the sedimentary rocks and the crystalline series, given in the accompanying map (p. 276). Where that boundary has been ascertained by me in the field, it is shown as an unbroken line; but these portions are necessarily small, and must be connected by supposititious broken lines, until the accurate survey of the country and subsequent exploration permit of filling them in definitely.

Whether there is any correlation between the sandstones of Nyasaland (mentioned by Prof. Drummond) or the sedimentary beds found at Tete, some 250 miles down the Zambesi River, and those of Matabeleland, I am not in a position to state; but Livingstone noted the similarity of some sandstones which he saw at Tete with a deposit existing north of the Zambesi near Binga's Kraal. The northernmost part that can here be given of this boundary-line in Southern Rhodesia begins beyond the Sanyati River, where the unconformity was noticed by Mr. Alford. It then takes a southerly direction as far as the lower end of the Mafungabusi Range, crosses the section shown in fig. 2 (Pl. XIX) near the Djombi River, and circles to the west round the Lower Gwelo gold-belt. A tongue of fine sandstones then is found between the Gwelo and Umvungu Rivers, Sonambula Forest; the same rock occurs on the old Hunters' Road north of Inyati, and it then runs between Shiloh and the Queen's Mine. At Shiloh the contact with the metamorphic rocks is masked by basalt. Another strip of sandstone runs over the schist to form the prominent flat-topped hills near Bulawayo, known as Thaba 'Sinduna, where, owing to the induration of the deposits by igneous rocks, the beds have arrested denudation, and the hill gives a section (to a height of 200 feet) of a formation that would otherwise have been completely swept away. The investigation of this hill with its siliceous secretions, agates, etc., should be one of the first special objects of the local geologist. The contact then runs west of Bulawayo through Helen Vale to Pasipas Mountain, where a hard red siliceous sandstone is being extensively quarried and supplies an excellent building-stone for that town.

My next acquaintance with the sandstone is at Macloutsie River on the railway-line; but, before reaching that point, it circles round the western end of the granitic Matoppo Mountains and the schists of the Tati gold-belt, and is met with on the road to the Zambesi Falls, to which it almost extends, forming a dry, sandy, barren



Forest Sandstones
Coal-bearing beds (Matobola Beds with Busse Beds between)
Sijarira Series
Samkoto Series
Crystalline rocks, granite, schists, & gold-belts.
Lavas & basalt
GEOLOGICAL SKETCH-MAP
of part of
SOUTHERN RHODESIA.
ZAMBESI RIVER
Sanyati R.
Section
Section along Road
SIJARIRA SERIES
Sengwe Coalfield
Sesami Coalfield
Lubu Coalfield
Great Escarpment
Section
Mazoe
SALISBURY
Hartley Hill
Gwai R.
Main Section
FOREST SANDSTONES
Bembesi Gold-belt
Great Desert
Gwelo
Sandstone Quarry
Thaba Sinduna
BULAWAYO
Victoria
Tokwe R.
Lundi R.
Nuanetsi R.
CRYSTALLINE ROCKS
LAVAS
Fort Tuli
Tuli R.
Mechels
Macloutsie R.
TULI
GRANITE
Limpopo R.
Section
SAMKOTO SERIES
Palapye
Koppie
Chopong
Mapani Pan
Scale of Miles
0 20 40 60 80 100

country, with roads that give heavy pulling for ox-waggons. West of this point lies the great Kalahari Desert, extending for several hundred miles across this portion of South Africa—a region which receives and soaks up the waters of the many rivers that run towards it from the high country around. The formation of the desert is entirely sedimentary, and the great salt-pans of Karikari and Ntwetwe, the deposits of calcareous tufa, the brackish water in the water-holes, and the traces of old river-courses, are all evidences of a gradually-drying basin of great extent.

At Macloutsie the surface of the sedimentary beds lies at an altitude 1000 feet lower than when last noticed at Pasipas Mountain, and here they become carbonaceous, varying from shales to conglomerates. They are almost at the same horizon as the commencement of the carbonaceous beds to the north. The railway crosses several shallow tongues of shales, as at Sisi close by (where some of the fossil plants described in Appendix III, p. 288, were obtained), and then the boundary keeps to the west, and sweeps round at Dikabi, past the indurated Chopong Hills at Palapye, and turns eastward towards the old Macloutsie police-camp. Near there, the contact between the Archæan and the sedimentary beds is hidden by the extensive lava-flows and tuffs of the Tuli district. At Umsingwane Drift on the Pioneer Road, a small outlier of highly-altered fine sandstone occurs, and on the Bubi River, 60 miles to the east, a narrow strip of the Samkoto Series shows between the gneiss and the lavas. Outliers of sedimentary deposits occur farther east towards the Sabi River, and various isolated patches of coal-bearing strata occur in that direction: these seem to be the remnants of a large area of sedimentaries occupying what is now the Limpopo Valley, most of which has been removed by denudation. As we have already seen (p. 274), small areas of sedimentary deposits occur along the southern fringe of the Tuli Lavas, while long ridges of the peculiar fissured sandstone of the Samkoto Series extend across the Limpopo into the Northern Transvaal.

Sedimentary deposits of varying lithological features thus border three of the slopes of the plateau of Archæan rocks that forms the backbone of Southern Rhodesia. In the Limpopo Valley, only small areas remain, but on the west, forming the great Kalahari Desert, and on the north as far as the Zambesi River, the derived deposits are of great extent—they even stretch beyond that river and abut against the southern slopes of the Zambesi-Kafué watershed.

On the south-west isolated areas of fine sandstones occur along the railway-line, and it may be possible that these are but outliers of the beds of the Great Desert, forming some connection with the strata of the Karoo and Kimberley Series. This has only been gleaned by observations in a railway-journey, when portions of the country were passed during the night; but there seems reason to believe that Rhodesia is merely the north-eastern shore of the sea of sediments which stretches as far as the Karoo.

Except in the case of the Tuli district, and the distinct break in

stratification between the Samkoto Sandstones and the coal-bearing beds, there appears to be no evidence of any unconformity whereby the large area and great thickness of sedimentary beds of Southern Rhodesia might be divided or grouped into separate systems—river-deposits and superficial accumulations excepted. Fossils have only been found in the beds associated with the coal-bearing strata, and thus there are no palæontological reasons for dividing the rocks into groups. There is only the general basis of superposition, and from the sections given, and from their characteristic lithological features, the rocks naturally fall into certain groups. No attempt is here made to correlate the strata of Southern Rhodesia with the Cape and Karoo systems; and so, for the present, I have ventured to apply names to the groups, taken from the localities where each is most typically developed.

The following provisional classification of the sediments that lie between the higher plateaux of Southern Rhodesia and the Zambesi River is accordingly suggested:—

	Thickness in feet.	
Thaba 'Sinduna Series .	200	Sandstones and volcanic rocks of Thaba 'Sinduna and Shiloh.
Forest Sandstones	1000	Fine sandstones of the forest-country, with sandy clay. Travertine on the surface. Bubi, Gwampa, and Sikonyaula basalts. Conglomerate-basement near the Djombi River.
Escarpment-Grits	400	Coarse red sandstones, with subangular pebbles, as seen in the great escarpment which stretches from the Mafungabusi Mountains to near Wankie's.
Upper Matobola Beds... (with coal-bearing beds: fossiliferous).	300	Clays, shales, ironstones, limestones, and impure coals of the Matobola Plains, from the Mafungabusi Mountains to the Gwai River.
Bussé Series .... (local only?: fossiliferous).	300	Fissile sandstones, grits, and conglomerates, with well-rounded pebbles.
Lower Matobola Beds... (with coal-bearing beds).	200	Shales and workable coal-seams. And at the base Fine, fissile, ripple-marked sandstones (carbonaceous).
Sijarira Series............	2000	Quartzites, indurated shales, and current-bedded sandstones and grits of Sijarira and the Zambesi.
Great unconformity.		
Basement-rocks		Gneiss, red and white pegmatite, and coarse granite, of Mafungabusi and the Lubu Gorge.

In the Mafungabusi district there has been no uptilting of lower beds, and the thickness of the sedimentary strata must be ascertained by the erosion of horizontal beds, reckoned from the highest sandstone of the Mafungabusi Mountains (3000 feet) to the Zambesi (1100 feet), a depth of 1900 feet.

The altitude of Thaba 'Sinduna is 4600 feet above sea-level, or 1600 feet above the Mafungabusi Mountains, and thus in the north-

eastern districts a thickness of 1600 feet of horizontal strata is unrepresented: these, if ever deposited, have been subject to erosion.

The difference of altitude between the Zambesi River and Thaba 'Sinduna is 3500 feet, which, allowing for the dip of the beds in the Sengwe Coalfield, and for further strata below Zambesi-level, must give a minimum thickness to the sedimentary deposits of Southern Rhodesia of 4700 feet.

The largest area in which the beds have been tilted is that around the Sijarira Range, and it is along a line following a north-easterly direction. While the summits of the range show some curved or folded strata, it is noteworthy that the rocks at the base of the range on the north side are unaltered and horizontal—thus proving the crumpling to be merely local. On the north-east the elevatory movement died out, and on the south-west the dip veers round to that direction.

Along the Sengwe Coalfield, the parallel direction of the escarpment, the plains, and the Sijarira Range is very noticeable, and this is owing to the tilting of the beds by which the softer coal-bearing strata have been exposed to more rapid decay. At present the Matobola Plains, which run along the strike of the coal-bearing beds, occupy a trough between the escarpment and the uptilted edges of the lower group of sandstones; and this depression continues for over 100 miles across this portion of the country. By the quicker decay of these beds, and the consequent trough-like valley thus formed, the rivers draining this area have had to force their way through narrow gorges in the Sijarira Range and the mountains lying between the plains and the Zambesi. The gorge of the Lubu has already been referred to. The Sengwe, which rises on the high plateau to the south, and descends to the Matobola Plains, is joined by many rivers that drain these flats, and also runs through the range of hills to the north by a deep and narrow gorge. Farther east again are the Sesami River and the Bumé (or Omay), which also cut their way through the hills from the flat country drained by them.

Where the quartzites or indurated rocks occur, it may often be noticed that there is a fault-fissure or displacement, and the axes of these movements take a north-easterly direction, or at right angles to the dip.

Thus at Chongolo the rocks are indurated on either side of a dyke of shale-and-sandstone crush-breccia. At the Lubu are parallel dykes of crush-breccia, made up of angular blocks of red sandstone, cemented by secondary white silica; and at many other localities it is noticeable that movements have taken place along lines following a north-easterly direction, and have crushed the rocks into angular fragments, now cemented together.

In no place have I yet seen two beds of different characteristics brought into proximity by these larger earth-movements, and the vertical displacement of the strata cannot be ascertained. The thickness of the few varieties of coarser sediments is so great that the dislocation might be immense without bringing rocks of different

character together. There are minor faults in the coal-seams, but in those observed the downthrow is only a few inches.

The regional alteration extends for some distance on either side of these lines of breccia, and the indurated rocks, resisting erosion better than the unaltered loose-grained sandstones, consequently form the core of the ridges, hills, and mountains of this part of the country.

IV. The Fossil Remains.

In investigating these stratified areas, the importance of fossil remains in determining their position in the geological record has been continually borne in mind; but, while constant search was made, it was long before specimens could be found. The splitting-up of rocks was seldom successful, and eventually it was found best to examine the weathered surfaces of blocks in the open.

The mounds of travertine occurring as superficial deposits from thermal springs enclose recent land and freshwater shells, such as *Pupa*, *Planorbis*, and *Limnæa*, and are associated with silicified trees.

The red strata of the Forest Sandstones and Escarpment-Grits have so far yielded no fossils, for their loose texture is not favourable to the preservation of organic remains, and there are few exposures of finer and more compact sediments to search.

The Upper Matobola Beds yield bivalve shells of unioniform appearance, in an impure limestone near Gunyanka's Kraal. On the top of a slight rise, 3 miles south-east of Nkoka's Kraal, a ferruginous shale contains similar but smaller specimens. In weathered slabs near Gunyanka's, and embedded with these shells, numerous pieces of bone are found, but in only two cases is there any definite shape—one resembling a small shoulder-blade, 3 inches long, and the other a phalangeal bone 4 inches in length.

The buff and greenish clays of these beds contain calcareous concretions, which, on decay of the softer portions, lie like shingle on the surface of the plains. These are frequently septarian, but the nucleus, when it can be separated out, never shows any definite organic form. A pale-grey clay, lying near the base of these beds, yields broken frustules of diatoms.

The finer ferruginous portions of the Bussé Series—which intervenes between the two groups of coal-bearing strata, or Matobola Beds—contain impressions of *Sigillaria* and *Calamites*, and numerous detached scales and imperfect bones of fishes. These fossils may be found both east and west of Nkoka's Kraal, on weathered blocks, and chipping open these rocks seldom results in larger or better-preserved specimens being secured. The large slab exhibited at the reading of this paper was found at the foot of the left bank of the Bussé River, 4 miles west of Nkoka's Kraal, where a capping of fine ferruginous sandstone is seen to overlie dark shales. On other blocks were many more fish-scales, but nothing so clear as the tail and bones of the ganoid fishes contained in this slab.

Learning caution from previous disappointments in trying to chisel out other fossils, I decided to secure the slab as it stood, and place it in the hands of the palæontologists of the British Museum (Natural History). It was accordingly conveyed to Bulawayo by Scotch cart and brought home. The fish-remains have since been examined by Dr. A. Smith Woodward, F.R.S., and his description forms the first Appendix to this paper (p. 285).

The coal-seams which crop out at the Horseshoe Cliff, on weathering, expose prostrate and flattened trees, a specimen exhibited at the reading of this paper being portion of a trunk over 12 inches long. Its outer coating is yellowish and soft; but this is due to weathering, as the interior is dull black and compact, and shows lines of growth. Fragments of such silicified trees are numerous along portions of the Matobola Plains, where the decay of the upper beds has left the fossils strewn on the surface.

At Sisi Siding, on the railway to Capetown, a well had been sunk through the soft shales referred to on p. 272, and faint impressions of *Glossopteris* were found in these in March 1900.

In the Tuli Coalfield, in a bed of shale lying between coal-seams, an impression of a calamite was obtained.

The mollusca and plants are described in Appendices II & III (pp. 287, 288), the latter by Mr. E. A. Newell Arber, M.A., F.G.S., and the former by Dr. Wheelton Hind, F.R.C.S., F.G.S., to whom, and also to Dr. Smith Woodward for his description of the fishes, I am under a deep and grateful obligation.

V. The Coal-Deposits.

The carbonaceous shales and clays that are associated with seams of coal crop out over a very large area, commencing near the junction of the Bumé (Omay) and the Zambesi Rivers to the north-east, and continuing in broken order as far as the Wankie Coalfield to the west. The area of these exposed beds covers over 1600 square miles, but it is not claimed that coal in workable seams exists to the same extent. In the Mafungabusi district the beds lie horizontally, and thus may mask a great thickness of coal-bearing strata which only deep boring could prove. There are, however, outcrops of small seams, and there are sufficient reasons for their being designated as the Mafungabusi Coalfield and Sesami Coalfield respectively.

During past years a limited amount of prospecting took place in these tracts, but, so far as can be ascertained, with little success. The Sesami Coalfield lies in a corner of the exposed portion of the Upper Matobola Beds, here 400 feet thick, and the seams are of poor quality.

Farther west is the long and extensive Sengwe Coalfield, where, owing to an upheaval of the strata, the lower series of Matobola Beds, containing seams of coal of good quality, are revealed. Extensive development has been accomplished here, and so far an area of 8000 acres has been found to contain a main seam of an average width of 5 feet, besides others of great thickness.

Twenty-five miles to the west is the Lubu Coalfield, where at the time of writing no work has been done. The seams crop out in the river-bed, and are $8\frac{1}{4}$ feet thick. The area of this field exceeds 30 square miles.

The Sebungu Coalfield, 20 miles still farther west, has also been neglected in development. There are many seams in the river-bed, one of 4 feet and others totalling $5\frac{1}{4}$ feet. The area of the exposed coal-bearing strata is 100 square miles.[1]

The Tuli Coalfield lies 190 miles south of Bulawayo, near the Limpopo River. It is several square miles in extent, but only about 1500 acres have been proved by development. The coal is semi-bituminous, on an average $3\frac{1}{2}$ feet thick.

The Massabi Coalfield lies 6 miles south-west of the foregoing. It covers an area of 10,000 acres, and is now undergoing development. So far two seams, respectively 4 feet and 6 feet 1 inch thick, have been struck. The coal differs greatly from other Rhodesian coals in being clean, with metallic lustre, and does not soil the fingers.

On the Sabi River in the south-east, another coalfield has recently been found, and is yielding good coal.

VI. The Thermal Springs and Travertine-Beds.

A special feature of the northern districts is the prevalence of mineral springs, varying from steam-jets and fumaroles, as at Zongala, and streams of boiling water of several hundred gallons per minute, as at Tchabi's, to mere percolations of saline water, yielding the salt collected from the soil by a process of lixiviation by the natives at Selayo, Nkoka's, Sitanga's and Tchabi's—and indeed at many places along the area of the coal-bearing beds.

While the gently-rising springs depositing saline matter, and the warmer ones (as at Sitanga's) which contain sulphuretted hydrogen, are charged with substances taken up in solution from the underlying coal-bearing beds, the majority of the hot springs deposit sheets of siliceous travertine, and are the moribund phases of volcanic action represented by the extinct craters of the Wankie district.

They are but a remnant of a vast number that, in fairly recent times, sprang up among the sandstones of the Forest Series, for in the valleys of the Shangani, Pupa, Karna, and Golongolo Rivers, along the Great Escarpment, up the Sengwe River, and at the edge of the Sikonyaula basalt-sheet, there are innumerable heaps of travertine—rounded quartz-grains cemented together by silica, often assuming the shapes of roots, and enclosing shells of *Pupa*, *Limnæa*, *Planorbis*, and *Unio*. There are now no other signs of these springs, as they are quite extinct; but the travertine left by them protects the underlying sandstones, and forms the capping of small rises.

Near these mounds are fragments of silicified trees, sometimes 6 feet long, and showing root-stumps and circles of exogenous

[1] With regard to the Wankie Coalfield, see 'Colliery Guardian vol. lxxxiii (February 21st, 1902) p. 390.

growth. They are characteristic of the old siliceous spring-areas, and can be easily distinguished from the pieces of silicified wood derived from the decay of coal-seams in the Matobola Plains.

VII. Summary.

The geological history of Rhodesia, as set forth in the rocks under notice, furnishes only a few chapters on periods far apart.

In the metamorphic or Archæan series that constitutes the basement-formation of this part of the African continent, there is evidence of basic and perhaps sedimentary rocks indurated and cleaved by the lateral pressure due to intrusion of granite-masses, with the resulting lines of weakness or faults filled with vein-quartz. On the principle of the deep-seated origin of granites the thickness of the metamorphic rocks must have amounted to many thousands of feet, a mass which has been eroded to such an extent as to lay bare the intrusive granite-ridges now represented by the Matoppo Hills and other mountain-ranges.

Of the geological periods between the alteration of the metamorphic rocks and the deposition of the Sijarira Series, no representative formations have been found, although in Bechuanaland and in the Limpopo Valley areas of intervening rocks probably exist.

In the north-west, after a long period of waste and decay of the Archæan plateau, the land began to sink, and this depression extended across the present Kalahari Desert to the west, and seemingly included the area of the Karoo and Kimberley Beds on the south-west. In the basin thus formed the grits resulting from the erosion of the crystalline rocks of the plateau were laid down unconformably. That it was a shallow sea is shown by the constantly-recurring current-bedding in the 2000 feet of the Sijarira Series, and the area must therefore have been one of gradual subsidence.

As the height of the plateau was reduced by erosion, beds of finer sediments became more numerous, until conditions were favourable for the growth of vegetation now represented by the numerous coal-seams. These beds generally lie upon hard clay, not at all resembling 'seat-earth,' and no fossils have been found in the clay that could be taken for roots.

During a period intervening between the Upper and Lower Matobola Beds, a sudden rush of coarser sediments (represented by the Bussé Beds) shallowed the water and entombed large numbers of fishes, broken fragments of which can be found all along the outcrop of the grits. These fishes, so far, are the oldest remains discovered, and enable us to assign a Permo-Carboniferous Age to the Matobola Beds. In the lagoons of Upper Matobola time, molluscs of Unioniform type existed, and contemporaneous therewith lived unknown vertebrates (possibly amphibia).

From the base of the Escarpment-Grits coarser sediments predominate, and during their deposition vulcanicity became a prominent factor, and ultimately ejected lava-flows which were interbedded with

the Forest Sandstones—the same volcanic action being the first cause of the red colour of the beds of this portion of the country.

After the deposition of the Forest Sandstones, the region was subjected to a gradual and irregular upheaval, extending over the whole area. Nearest to the now reduced plateau the beds were but little removed from their horizontal position, but near the Sijarira Range there was greater displacement, and faults and dislocations of strata were frequent along what is probably a line of great weakness.

On the region becoming dry land, it is probable that desert-conditions prevailed in parts, for many of the sands in the neighbourhood of Shiloh are rounded in a manner that suggests æolian agency, and volcanic action again reached the surface in the basalt-sheets of that locality.

Since that period, in the area of the northern sediments, the country has been subject to continuous denudation, removing the higher sedimentary beds, and again exposing the basement-schists and granites to decay.

On the west the area of the Kalahari Desert was only partly raised, and it remained an inland sea into Tertiary times. But the deposits from the more elevated areas around gradually closed in, and are even now filling up the country; for the Kalahari, in the few years in which it has been known, has given evidence of the drying-up of the rivers flowing towards it, and the great lakes are becoming brackish, or exist only as salt-pans.

During later times the Tuli district was subject to a period of great volcanic activity, and this so recently that the cones remain as prominent hills, having characteristic curved slopes, especially noticeable around Fort Tuli.

These volcanic deposits are the last addition to the building-up of this portion of South Africa, which has since been at the mercy of processes of gradual erosion and decay, for even its débris find no resting-place in the country, but are carried away by river-systems to form the deltas at the mouths of the Zambesi and the East-Coast rivers.

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Appendix I.

On a New Species *of* Acrolepis *obtained by* Mr. Molyneux *from the* Sengwe Coalfield. By Arthur Smith Woodward, LL.D., F.R.S., F.L.S., F.G.S.

[Plate XX.]

The large slab of ferruginous sandstone obtained by Mr. Molyneux from the Sengwe Coalfield exhibits the imperfect remains of five ganoid fishes, besides scattered fragments probably of others, all belonging to the same species. One specimen (Pl. XX, fig. 1) indicates the approximate length of the head, two others seem to show the maximum depth of the trunk, while another displays the greater part of the heterocercal tail (Pl. XX, fig. 2). All the specimens exhibit the scales, and there are also some traces of the paired and anal fins. It is thus possible to determine many of the characters of the genus and species represented.

The fish to which these remains belong is laterally compressed, and must have measured at least 60 centimetres in length, with a maximum depth of about 15 centimetres. The length of the head with opercular apparatus seems to have been approximately equal to the maximum depth of the trunk. The caudal pedicle is clearly very slender, and the upper caudal lobe is much elongated (Pl. XX, fig. 2).

The external head-bones are ornamented with thick rounded rugæ, but they are crushed together beyond recognition. The direction of the mandibular suspensorium is very oblique.

The enamelled scales are thick, rhombic in shape, and regularly arranged over the whole of the trunk. They are very deeply overlapping; and those of the flank are united by a peg-and-socket articulation, without any strengthening ridge on the inner face (Pl. XX, fig. 4). The principal scales of the flank in the abdominal region (Pl. XX, fig. 3) are not deeper than broad, and their rhombic outline is slightly modified by a sigmoidal curve of the upper and lower margins. The thick enamel of their exposed face is sculptured with grooves, which separate about eight or nine rounded, horizontally-directed ridges, and these terminate at the hinder margin of each scale in coarse deep pectinations. The uppermost ridge is the

longest, extending the greater part of the distance across the scale, while the others gradually decrease in length to the lowermost, which does not extend forward beyond the posterior half of the exposed face. The triangular anterior area thus left free from ridges is marked by a few delicate lines parallel with the inferior margin, in fact coincident with the lines of growth. The dorsal and ventral scales of the abdominal region (Pl. XX, figs. 5 & 6), and apparently most of the scales of the caudal region, are longer than deep, though none are excessively elongated. They are as coarsely ornamented and serrated as the principal flank-scales already described, but their ridges are only from five to six in number, and their anterior striated area is relatively less in extent. The scales of the upper caudal lobe are of an elongate-lozenge-shape and almost or quite smooth. No ridge-scales are observable, except those of the upper caudal lobe, which are rather small, narrow, and smooth.

The rays of the pectoral fins (Pl. XX, fig. 1, *pct.*) have a long, unjointed, smooth basal portion. The pelvic fins seem to have had a moderately extended base-line, and the space between the latter and the anal fin is much less than the maximum depth of the trunk. The rays of the caudal fin are delicate and very closely articulated to the base, and the tail must have been forked.

This fish from the Sengwe Coalfield is clearly a member of the family Palæoniscidæ, and it belongs to that section in which the mandibular suspensorium is very oblique.[1] Though the teeth and dorsal fin are unknown, its general aspect leaves little doubt that it may even be assigned to a still more definite position in the small group of which *Elonichthys* and *Acrolepis* are typical representatives. Detailed comparison, indeed, shows that it is easily distinguished from all known genera of Palæoniscidæ except the two just mentioned; and it differs from *Elonichthys* at least in the very deep overlap of the scales. In the latter respect, and in all observable characters which may be regarded as of generic value, the newly-discovered fish agrees with *Acrolepis*, and to this genus it may accordingly be referred. It differs from the typical species of *Acrolepis* in the serration or pectination of its scales; but isolated scales with posterior serrations, from the Karoo Formation of Cape Colony, have already been referred to this genus with much probability of correctness.[2] The scales of the fish now described are readily distinguished from the latter by their peculiar external ornamentation; and they are similarly distinguished from all known species, even from those based by Dr. Traquair on scales from the north-western bank of Lake Nyasa.[3] The fish from the Sengwe Coalfield thus represents a new species, which may be named *Acrolepis Molyneuxi* in honour of its discoverer.

[For the Explanation of Plate XX, see p. 290.]

[1] A. S. Woodward, 'Catal. Foss. Fishes Brit. Mus.' pt. ii (1891) p. 428.
[2] *Acrolepis (?) digitata*, A. S. Woodward, *op. cit.* p. 508 & pl. xv, fig. 4.
[3] *Acrolepis (?) africana* and *Acrolepis (?) Drummondi*, R. H. Traquair in Drummond's 'Tropical Africa' (1888) pp. 193, 194.

Appendix II.

Notes *on some* Lamellibranchiate Mollusca *obtained by* Mr. Molyneux *from the* Sengwe Coalfield. By Wheelton Hind, M.D., B.S., F.R.C.S., F.G.S.

Four small slabs of sandstone obtained by Mr. Molyneux are covered with imperfectly-preserved bivalve shells, which seem to represent two species.

Three of these slabs, numbered 7, exhibit numerous specimens of a small oval shell, the largest measuring about 9 millimetres in antero-posterior length. Some examples show the surface-markings or casts left by an impression of the surface, while a few bear traces of the anterior adductor muscle-scar. They all have a markedly Unioniform aspect; but none appear to exhibit the hinge-plate, which is a very important factor in determining the genus to which they belong.

Prof. Amalitsky has shown [1] that in the Permian beds of the Oka-Volga Basin there occur several genera of Unioniform shells, for the generic determination of which the hinge-characters are essential. The same author has studied the collection of lamellibranchs from the Karoo Formation of South Africa in the possession of the Geological Society, and has recognized several species identical with those from the Permian near Nizhni Novgorod. I have had the privilege of examining Prof. Amalitsky's type-specimens in St. Petersburg, and, in his company, the beds in which they were discovered near Nizhni Novgorod. I have also studied the Bain Collections from South Africa, in the Geological Society's Museum, used by Sharpe. On the whole, my biological results agree with those of Prof. Amalitsky, and I only differ from him on mere questions of nomenclature. I think that the small oval gibbose bivalves discovered by Mr. Molyneux in the Sengwe Coalfield should most probably be referred to the group named *Palæomutela Keyserlingi* by Prof. Amalitsky. This species is probably alluded to by Prof. T. Rupert Jones in Geol. Mag. 1890, p. 558, as *Cyrena (?) neglecta.*

The fourth slab, numbered 9, is filled with numerous badly-preserved specimens of a bivalve which is much more transversely elongate than *Palæomutela Keyserlingi.* The specimens are too much eroded to be named with any degree of accuracy. It may, however, be noted that at Graaf Reinet, shells of the form of *P. Keyserlingi* are associated with elongate types, which Prof. Amalitsky [2] has recognized as *Palæomutela subcastor*, *P. semilunulata*, and *P. rhomboidalis* (Sharpe). One of these may be represented by the shell now under discussion. At one corner of the slab I think that I can see a portion of the typical hinge of *Palæomutela.*

[1] 'Ueber die Anthracosien der Permformation Russlands' Palæontographica, vol. xxxix (1892) p. 125.

[2] 'Comparison of the Permian Freshwater Lamellibranchiata from Russia with those from the Karoo Formation' Quart. Journ. Geol. Soc. vol. li (1895) pp. 337–49 & pls. xii–xiii.

Appendix III.

Notes on some Fossil Plants collected by Mr. Molyneux in Rhodesia. By E. A. Newell Arber, Esq., M.A., F.G.S., Demonstrator in Palæobotany in the University of Cambridge.

The fossil plants from Rhodesia collected by Mr. Molyneux, and presented by him to the British Museum (Nat. Hist.), are, so far as I am aware, the first specimens to be described from this region. They were obtained from three different localities. The most noteworthy are those from a small area of fine horizontal sedimentary beds, resting on nearly vertical metamorphic rocks, at the Sisi siding on the Bechuanaland Railway. Two of the specimens [V 7592–93][1] from this locality contain fairly well-preserved fronds of the fern-like plant *Glossopteris Browniana*, Brongt., and of some of its varieties.

Some of these fronds are remarkable, as showing what I think may possibly prove to be the imprints of the sori or the sporangia. Our present knowledge of the reproductive organs of *Glossopteris* is very unsatisfactory. Nothing whatever is known as to the structural features of the sporangium. The position of the sori or of the sporangia on the frond is still doubtful, for the markings exhibited by certain fronds of this plant, which were regarded by Bunbury and Feistmantel,[2] and more recently by Prof. Zeiller,[3] as indicating the position of the sori, may have had no real connection with the fructification. The markings consist of fairly-large, circular, or oval spots or holes, usually lying in two or more longitudinal series on either side of the midrib. As has been pointed out by several authors,[4] these certainly suggest that the position of the sori may have been similar to that of certain recent Polypodiaceous ferns. In the absence, however, of any evidence connecting these holes with the occurrence of sporangia, their origin may possibly be accounted for in other ways.

Several months ago, while examining some specimens of *Glossopteris* from the Lower Gondwanas near Bhuwan (India) in the Geological Department of the British Museum, I was struck by the peculiar appearance of some of the fronds. Along the midrib, and usually arranged in four or more parallel lines, there occur longitudinal series of quite small protuberances or pits. The latter are considerably smaller than a pin's head. When I came to examine the specimens from Rhodesia, I was surprised to find almost exactly the same appearance as in the Indian specimens. The rows of small, circular, or oval protuberances or minute knobs (or, in the majority of the Rhodesian specimens, small dot-like pits), are confined entirely to the region of the midrib, or to an area slightly broader than the midrib. I have not so far succeeded in

[1] Registered numbers of specimens in the Geological Department of the British Museum (Natural History), South Kensington.

[2] Feistmantel, Pal. Indica, ser. 12, 1881, 'Fossil Flora of the Gondwana System' vol. iii, pt. 3, p. 97, pl. xxvi A, figs. 1–4, & pl. xxvii A, figs. 1, 2, 5.

[3] Bull. Soc. Géol. France, ser. 3, vol. xxiv (1896) p. 370 & pl. xviii, figs. 3–3′.

[4] Seward, Quart. Journ. Geol. Soc. vol. liii (1897) p. 319.

finding any trace of a sporangium, and it is by no means certain at present that these small protuberances, or the pits which probably result from the removal of the protuberance, are at all connected with the fructification. These characters do, however, recall the position and type of sori met with among certain recent ferns, especially the Polypodiaceous genus *Blechnum*, and the provisional suggestion, that these markings really indicate the position of the sori on the frond, is not open to some of the objections that can be raised against the specimens which have previously been described as showing the position of the fructification. I hope to undertake a further examination, and to give a fuller account of these interesting specimens, before very long.

The occurrence of *Glossopteris* in Rhodesia is interesting, but not perhaps very remarkable, for the *Glossopteris*-flora has already been described from regions both to the north and the south of that province. From the neighbourhood of Johannesburg, Prof. Zeiller[1] and Mr. Seward[2] have examined a most interesting flora of this type, and Prof. Potonié[3] has shown that *Glossopteris* occurs as far north as German East Africa. The evidence of the plants from Sisi helps to fill in a gap between these two distant regions, and would tend to confirm the impression that there may be a considerable development and a wide distribution of *Glossopteris*-bearing rocks in Southern Africa, as in Australasia.[4] The age of the beds in which the *Glossopteris*-flora is typically developed in India, Australia, and elsewhere is usually regarded as Permo-Carboniferous. While it would be unwise to attempt to determine definitely the horizon of the beds at Sisi from the evidence of a single plant, there is at least some probability that they may eventually prove to be of similar age. It would be a matter of great interest if further specimens could be obtained to determine this point, and also whether the remarkable association of northern and southern plant-types, found in the beds near Johannesburg, occurs also in Rhodesia.

The Tuli Coalfield, lying some distance to the south of Bulawayo, is represented in Mr. Molyneux's collection by a single plant-remain [V 7597] found between two seams of coal. This is a pith-cast of a plant somewhat closely resembling a European Carboniferous calamite, such as *Calamites* (*Calamitina*) *approximata*, Brongt. The structural features of the surface of the cast are, however, hidden by a layer of coal, and the preservation is not perhaps sufficiently good to warrant more than a reference to *Calamites* as the probable genus to which the specimen belongs.

The three remaining specimens are from the Sengwe Coalfield, about 150 miles from Bulawayo in Northern Matabeleland, and belong to a horizon termed by Mr. Molyneux the Matobola Beds.

[1] Bull. Soc. Géol. France, ser. 3, vol. xxiv (1896) p. 349.
[2] Quart. Journ. Geol. Soc. vol. liii (1897) p. 315.
[3] Sitzungsber. Gesellsch. Naturf. Freunde zu Berlin, 1899, p. 27.
[4] T. W. E. David, Proc. Linn. Soc. N. S. Wales, ser. 2, vol. ix (1894) p. 249.

One of these [V 7595] is a piece of petrified wood from a coal-seam. Such specimens are stated to be very numerous in this coalfield. The other two specimens belong to a typical European genus of Carboniferous age. One of these [V 7594] is a portion of a stem which measured 12 inches across, and occurred above the coal in this coalfield. The stem bears a number of vertical ribs, and recalls the structure of a decorticated stem of *Sigillaria*. This conclusion is confirmed by the occurrence of a faintly-marked leaf-scar of the Sigillarian type on one of the ribs, and there is little doubt that the specimen is a Eu-Sigillarian stem of the *Rhytidolepis*-type. The remaining specimen [V 7596] is of a similar nature.

The collection from the Tuli and Sengwe Coalfields is too small to offer any evidence as to the horizons of the beds. Coalfields, with floras for the most part specifically identical with those of European Upper Carboniferous rocks, are already known, both to the north-east of Rhodesia, in the Teté [1] Coalfield of the Zambesi, and to the south, in coalfields in the Cape Colony [2]: in both of these *Calamites* is stated to occur. On the other hand, *Sigillaria* [3] occurs in South Africa in association with the *Glossopteris*-flora. The occurrence of typical European Coal-Measure plants in the above-mentioned coalfields, without any trace of members of the *Glossopteris*-flora, is very remarkable, and has an important bearing on the question of the exact age of the *Glossopteris*-bearing rocks in South Africa and elsewhere. It is therefore highly desirable that we should know more of the floras of the various coal-bearing basins in South Africa.

EXPLANATION OF PLATES XIX & XX.

PLATE XIX.

Fig. 1. Main section, from Bulawayo to the Zambesi River. Horizontal scale: about $9\frac{1}{2}$ miles = 1 inch.

2. Section from the Sinanombi gold-belt to the Sesami Coalfield. Horizontal scale: about $9\frac{1}{2}$ miles = 1 inch.

3. Section from the Lubu Coalfield to the Zambesi River. Horizontal scale: 4 miles = 1 inch. ['Syarira' in this section should be spelt 'Sijarira.']

4. Section from near Macloutsie to Mokoro. Horizontal scale: about $9\frac{1}{2}$ miles = 1 inch.

PLATE XX.

Acrolepis Molyneuxi, sp. nov., from the Permo-Carboniferous of the Sengwe Coalfield, Southern Rhodesia. [Brit. Mus. No. P 9840.]

Fig. 1. Right lateral aspect of imperfect head and abdominal region, about two-fifths nat. size: *br.* = branchiostegal rays; *pct.* = base of pectoral fin.

2. Imperfect tail of another individual, about two-fifths natural size.

3. Some principal flank-scales, outer aspect, natural size, displaced to show the overlapped portion.

4. Flank-scale, inner aspect, natural size, imperfect at the digitate hinder margin.

Figs. 5 & 6. Ventral scales, outer and inner aspects respectively, natural size.

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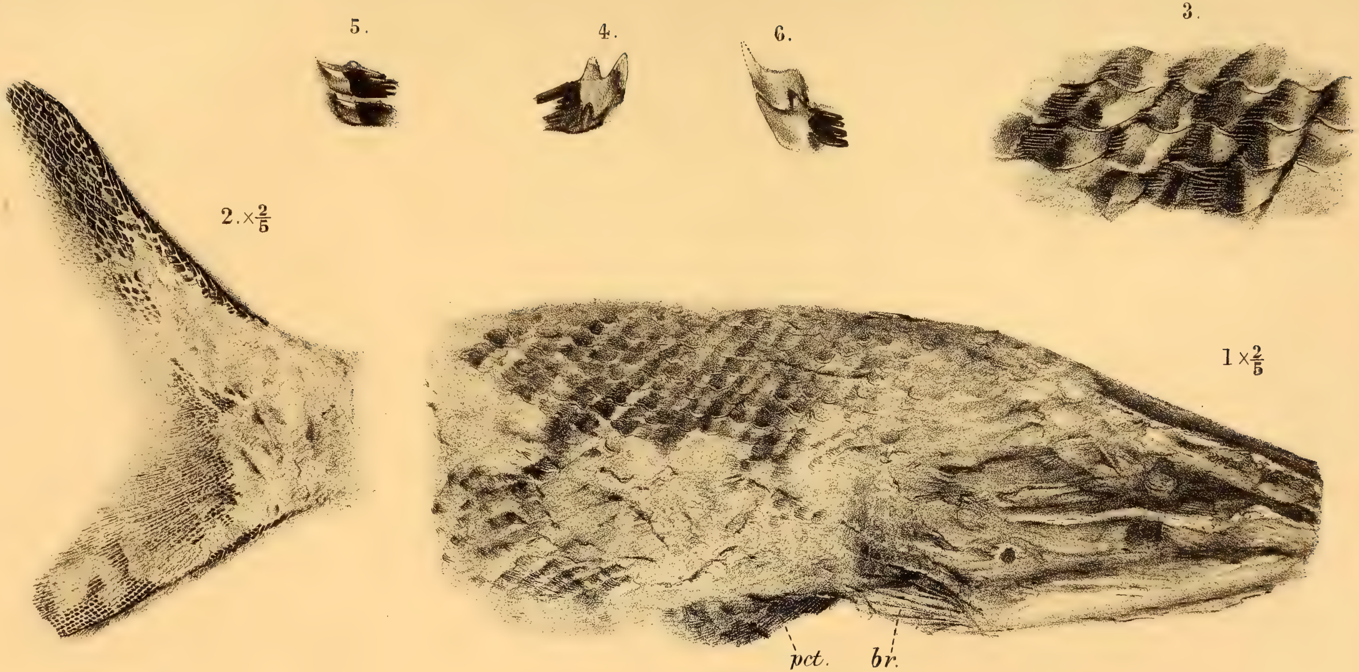
[1] Zeiller, Ann. des Mines, ser. 8, Mém. vol. iv (1883) p. 594.

[2] Grey, Quart. Journ. Geol. Soc. vol. xxvii (1871) p. 49.

[3] Seward, *ibid.* vol. liii (1897) p. 315.



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ACROLEPIS MOLYNEUXI, sp. nov.

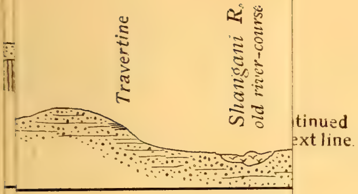
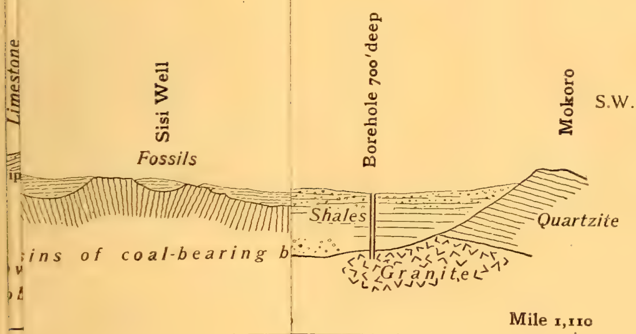


Fig.4.- Section



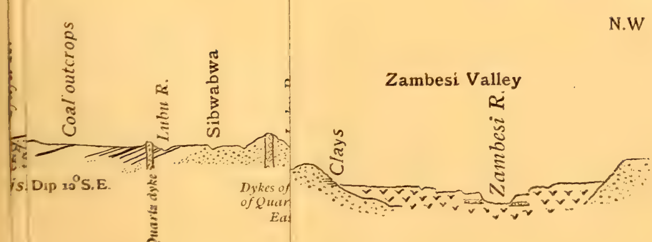


Fig.1.-Main Section:- Bulawayo to the Zambesi River.

Horizontal Scale:-about 9½ miles=1 inch.

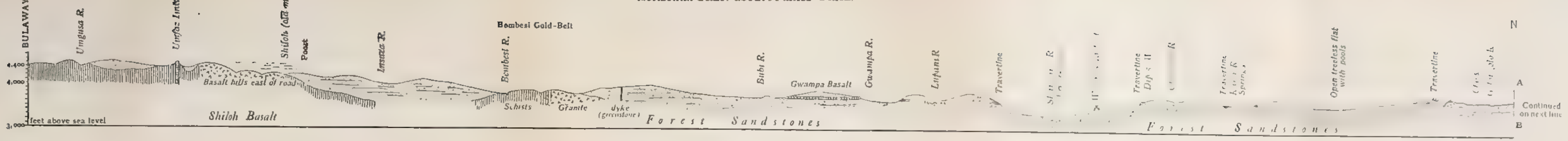


Fig.1.-Main Section (continued)

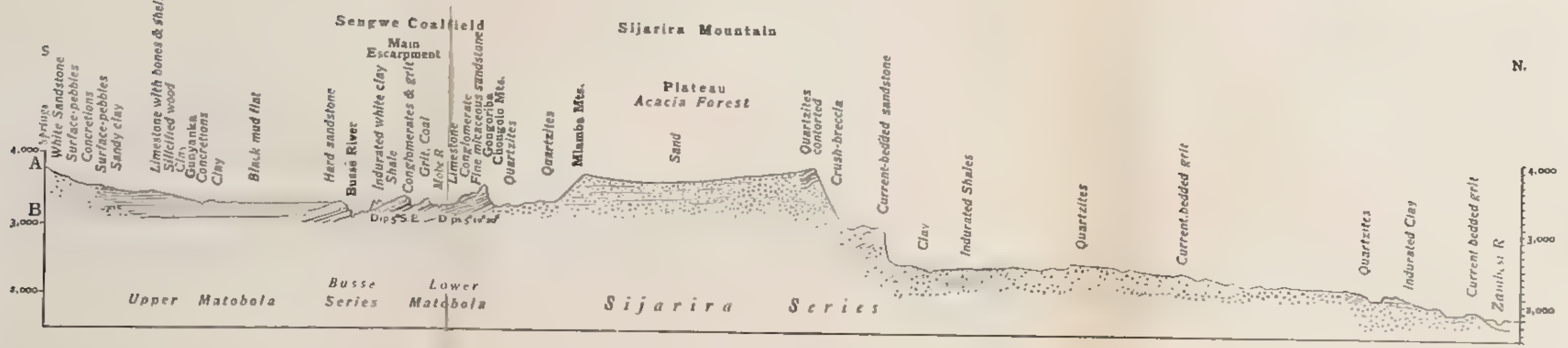


Fig.4.- Section showing the fringe of Sedimentary Deposits on the Railway to the South-West.

Horizontal Scale about 9½ miles=1 inch

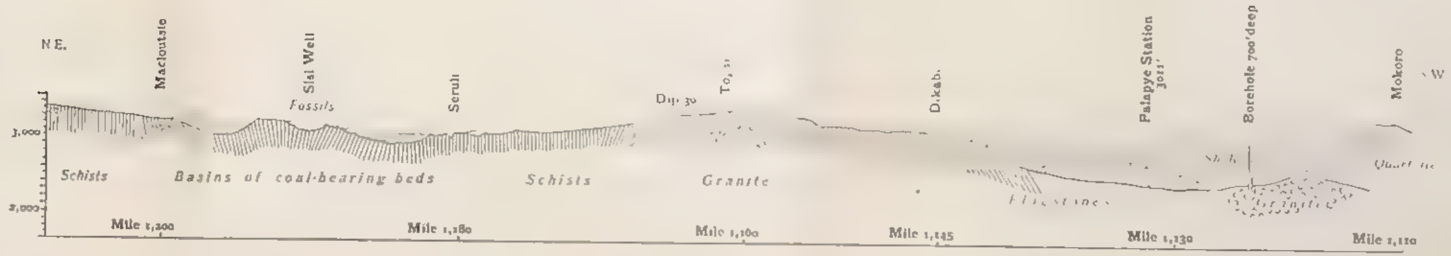
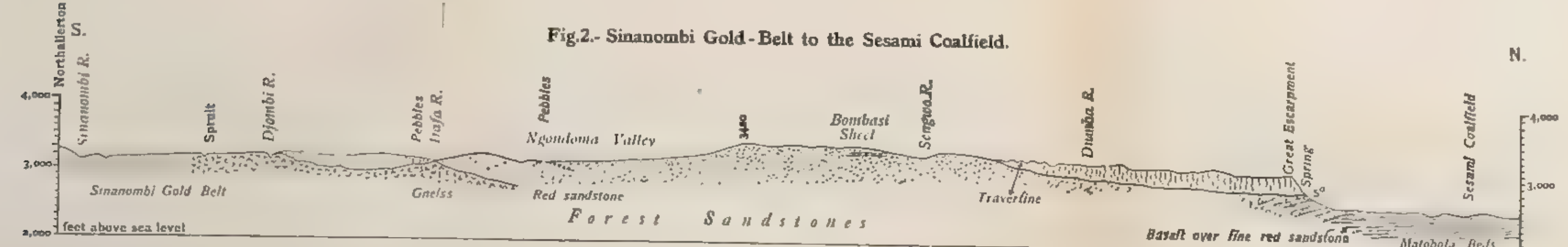


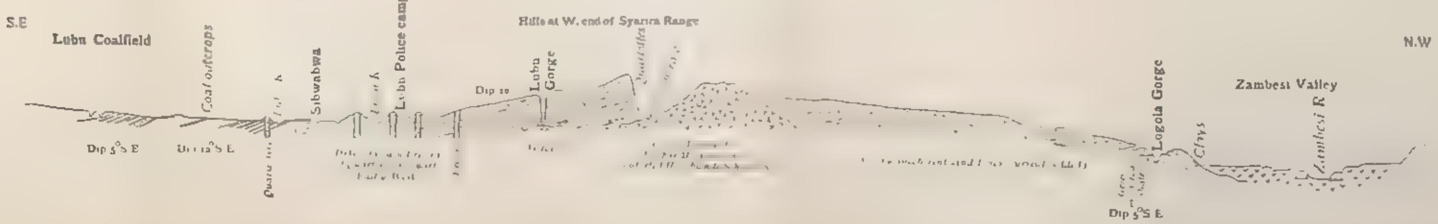
Fig.2.- Sinanombi Gold-Belt to the Sesami Coalfield.



[Horizontal scale: about 9½ miles=1 inch.]

Fig.3.- Lubu Coalfield to the Zambesi River.

Horizontal Scale:-4 miles 1 inch.



Discussion.

The President said that the Society sincerely welcomed papers of this nature, dealing with the general geology of some of the broad 'borderlands' of the Empire, of the structure of which so little was as yet known. Especially was it interesting to note how large a proportion of the results appeared to be due to the Author's own travels and observations.

Mr. C. J. Alford said that he had nothing to add to the paper but corroboration. The expedition which he had conducted in the Zambesi Valley was undertaken on behalf of the British South Africa Company about ten years ago, and was attended with disastrous experiences. All the oxen and horses were killed by the tsetse fly, and the men died of malarial fever: he and one other (Lieut. Carden) only reaching Salisbury, after walking back nearly 400 miles, with nothing left but their lives. Most of the specimens of rocks and other things which had been collected were lost.

The Author thanked the President for his appreciative remarks, and the Fellows present for their kind reception of the first paper that he had brought before the Society.

21. Petrological Notes on Rocks *from* Southern Abyssinia, collected *by* Dr. Reginald Kœttlitz. By Catherine A. Raisin, D.Sc. Lond. (Communicated by Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S. Read March 11th, 1903.)

[Plate XXI—Map.]

Contents.

I. Introduction.

An interesting account of a journey into Southern Abyssinia was given in the Journal of the Royal Geographical Society for 1900, by Mr. H. Weld Blundell.[1] He followed a route roughly westward from Berbera through Somaliland and Southern Abyssinia, then turned northward to the Blue Nile and into the Sudan. On this expedition Dr. R. Kœttlitz collected a large number of rock-specimens which (at the kind suggestion of Mr. Teall), together with some obtained by Lord Lovat, were entrusted to me for description.[2] The absence of the former on the Antarctic Expedition makes it impossible to submit these notes to him for revision. But the following brief statement is condensed from a topographical sketch which he posted to me from the ship *Discovery* at Lyttelton (New Zealand) in the spring of 1902, and a more general account by him will be found printed as an appendix to Mr. Blundell's paper mentioned above. A map of the route was published with that paper, from which I have copied the spelling for the place-names, where possible. I have identified a few other localities on the British War Office map of the district, but the remainder had to be taken from the rough pencil-labels.

The expedition crossed the coastal plain from Berbera, passing knoll-like isolated hills, the road gradually rising to the edge of the plateau, where the shattered rocky ground often exposed schistose and granitic masses. Overlying these, sedimentary beds and volcanic rocks were seen in places, and occasionally flat-topped basaltic hills occur. In the great volcanic district of Southern Abyssinia, sheets of basalt are often exposed, sometimes vesicular and scoriaceous, especially at the surface of the flows, sometimes exhibiting columnar structure. On the Hawash Plain, many hills are more or less complete volcanic cones, with the craters preserved.

[1] Geogr. Journ. vol. xv (1900) p. 97.

[2] Unavoidable delays occurred in the transmission of some of the collections, so that these notes appear somewhat late.

One of these, extinct, but perfect in form, 40 miles south of Addis Abbeba, is Mount Saquala, from which specimens of rocks have been brought. Farther west, beyond the Didesa River, older rock in places underlies basalts or similar volcanic deposits, but the main mass of the mountains is composed of disturbed and contorted schistose and granitic rocks.

The collection contains some specimens of structural interest, and further illustrates certain petrological features which we may perhaps associate with East African geology. Thus the presence of some pressure-modified Archæan rocks at certain zones, the abundance of volcanic masses, and the occurrence among these of soda-bearing types, will be gathered from the following account.

II. Crystalline Rocks.

I have grouped the granites and diorites with the gneisses and schists, as some specimens exhibit transitional characters. These rocks occurred mainly in two areas—one, south-west of Berbera; the other around the head-waters of the tributaries of the Blue Nile. At both localities the Archæan rocks seem to have been thrust up, and some of the specimens are crushed. Westward of the range bounding the coastal plain, they form a floor largely covered by overlying sandstones, limestones, and volcanic rocks of later epochs. According to Dr. Kœttlitz, they often exhibit a high dip with contortions and foldings.

(1) Granites.

The granites, both coarse- and fine-grained, some with porphyritic crystals, consist of quartz, felspar (often plagioclase or microcline), biotite, and occasionally apatite or zircon. In crystals formed of a micropegmatitic growth of two felspars, the alternate, roughly-parallel, irregular streaks are generally plagioclase or microcline. A grey granite with black biotite (from between Dabus and Jem Jem) encloses patches (2 inches or more across) of a close-grained blackish hornblende-schist or fluxion-diorite, as if one magma, and it is doubtful which, had intruded into the other.

Probably a dyke or vein is represented by a specimen from the same place, of a rather modified microcrystalline garnet-aplite. The felspar shows evidence of strain in its wavy cleavage-planes; and aggregates of white mica are doubtless derived from an original constituent, the residuum of which may have formed the small associated garnets. Other indications of pressure are found in some granites, although the most marked are in certain gneisses.

(2) Gneisses.

Some are normal, but many are pressure-modified, and certain of these are finely speckled (the 'pepper-and-salt' type). One hornblende-gneiss allied to a diabase, crushed and reconstituted, and other much modified specimens come from near Jibuli (Gibeli),

where the rocks were 'much tilted' and re-appeared 'again and again' on the journey. One of these, pale yellowish-grey with silvery surfaces, consists of lenticles of quartz-felspar mosaic, with white and pale brown mica along streaks or zigzag lines. In a much-crushed rock, from the same locality, the mosaic forming pinkish streaks contains coarse patches with mica- or chlorite-flakes, and crystals of felspar (orthoclase and plagioclase) much corroded. In another granitic rock the narrow red felspathic bands (bounded by lines of biotite) consist of a mosaic, either fine-grained, containing iron-oxide and some biotite, or coarse-grained with microcline, white mica, and a streak of a secondary mineral, possibly a zeolite. The rock probably owes its structure to fluxion-movements, and resembles marginal specimens from a Vosges granite, the structure of which I incline to attribute to this cause. (A gneiss from Gumbi, towards the Nile Valley, weathering red, has a granular matrix with streaky biotite and may be similar.) Another rock from near Jibuli, from the river-bed, is reddish, banded, compact and hälleflintoid, not unlike a rhyolite; but the constituent grains of the mosaic are often angular and clearly defined, so that (like some of the preceding specimens) it is probably a crushed and recrystallized gneiss, somewhat similar to certain Saxon granulites.

A pale-grey, medium-grained, holocrystalline rock, from the top of a steep hill on the road from Mendi to Gumbi (Gimbi), is composed of plagioclase-felspar and quartz, with ragged flakes of biotite, clear epidote, and some sphene.

(3) Hornblende-Schists and Foliated Diorites

are all blackish fine-grained rocks, containing plagioclase, biotite, hornblende, iron-oxide, with sometimes augite, and occasionally a zircon. One specimen, from north-west of Quattie Camp towards the Blue Nile Valley, is ophitic; but the structure in the rocks generally is granular and often fluxional, as in one south-west of Berbera, and in one towards Fyambiro, while two others exhibit a slightly-brecciated appearance. A schist from between the Dabus River and Jem Jem is undoubtedly crushed, traversed by narrow prisms of hornblende with a parallel arrangement. In another schistose rock from Gumbi (one specimen of it coming from the summit of the hill) bright brick-red and brown patches are present. These are rich in narrow prisms of (possibly) an iron-stained epidote, while the wavy bands of mosaic in the slice contain some iron-oxide. Small micaceous or kaolinized aggregates have been formed probably from felspar-crystals. The rock may be a much-crushed ferriferous diorite.

(4) Diabase; Hornblendic Gabbro; Pyroxenite.

These rocks all come from the South-west of Abyssinia, from localities where some granitic or dioritic rocks occur. A specimen from Gumbi exhibits green hornblende with patches of epidote and

(?) zoisite, within a mosaic in which the orientation is partly due to pressure. In another rock from beyond Jem Jem (containing a carbonate), the hornblende is ragged and fibrous at the ends, and, like the biotite, has undergone alteration, but whether by pressure is less certain in this example. Two rocks in the hand-specimens are like a typical gabbro. One, fairly coarse (from Govie, where the rock is said to extend for several miles, and from Gauti), is composed of felspar mostly fresh (probably labradorite), of dark-green, well-cleaved hornblende resembling altered diallage (often enclosing felspar), with epidote, apatite, and iron-oxide. The other (from the Didesa River), consisting of kaolinized felspar and of a platy green hornblende, partly recrystallized or aggregate, occurs in a junction-specimen with a speckled diabase (both containing epidote), but the passage is somewhat gradual, as if either they were parts of one mass, or the intruding diabase had carried off pieces of the gabbro.

A dark-greenish rock from the top of the hill between Donkoro and Bojji, resembles a picrite, with its large platy crystals ($\frac{1}{2}$ inch long) lustre-mottled. These are found to consist of green pleochroic hornblende, sometimes paler at the exterior. They enclose grains of a well-cleaved white augite, often brown-stained at the edges, which resembles that described by Prof. Bonney in the 'picrite' of Porthlisky, where olivine is also present.[1] In parts of this Abyssinian slice, the augite is intergrown with the hornblende as a granular aggregate, or in an almost micro-ophitic arrangement; and in places the augite is changing to hornblende, that is, the rock is a form of hornblende-pyroxenite.

III. Volcanic Rocks.

The collection includes a large number of volcanic rocks, most of them from Southern Abyssinia. The great majority are basalts and andesites, but phonolites or allied rocks occur, with one loose specimen of obsidian and some tuffs.

(1) Basalts.

(i) Olivine-basalt.—A blackish rock from the basaltic region between Gudr and Toki is compact, but crowded with large crystals, sometimes half an inch long. These are of augite or of olivine, the latter often a transparent peridote, but sometimes possibly fayalite. One specimen of the rock, with more groundmass, contains small whitish amygdales and lath-shaped felspar-microliths. In the olivine in another slice, curved cracks in one crystal slightly resemble perlitic spheroids within cross-jointed blocks, and the glassy magma extends along some cracks. The augite is brownish with a puce-coloured edge, and encloses some olivine. The groundmass is colourless, partly glassy, but includes felspar, and contains small

[1] Quart. Journ. Geol. Soc. vol. xli (1885) p. 519 & pl. xvi, fig. 5. The colourless augite is more or less distinct in the boulders from Anglesey, *ibid.* p. 518.

crowded crystals of augite and of iron-oxide. The specific gravity of three specimens (tested by a Walker's balance) is respectively 2·95, 3·09, 3·18, which is higher than that of an ordinary tachylyte (2·71 to 2·86). Thus, notwithstanding the presence of felspar (which, as Prof. Bonney has shown, is always potential and sometimes actual in the rock from Limburg itself [1]), the specimens really belong to the limburgites.

Olivine is a distinct constituent, although not abundant in a few other basalts, which often have a purplish tinge, and resemble the Niedermendig and allied rocks. The two most typical come from the Saquala district. One from the hillside between that mountain and Galanda Lotha is minutely microcrystalline, and contains larger crystals of augite and plagioclase, with a ferruginous olivine. This is bright brown, with metallic iridescence, in the hand-specimen; and under the microscope it resembles the brown-edged crystal changing to iron-peroxide figured by A. Rosiwal.[2] Several felspar-crystals have undergone partial melting-down, forming an outer cloudy or gelatinous-looking part, in which the iron-oxide has been deposited along the plagioclase-bands, by infiltration from the groundmass. A specimen from Tsingari is similar, but it contains more plagioclase, is more coarsely crystalline, and is lighter in colour than an ordinary basalt.

(ii) Basalts proper.—These are mostly microcrystalline, but in a few a little residual glass may occur. Several contain some ferruginous olivine, and occasionally plagioclase with a cloudy appearance, or granular patches caused by a melting-down of small crystals. Among these basalts from Somaliland are a purplish vesicular rock from the river-bed at Hamas, a specimen from near Addi Adeya from a talus (but 'tiers of rock probably similar appear above'), and one from the Hill of Sobolo (5854 feet), where a 'chalk-like rock fills the interstices.'[3] Several microcrystalline basalts come from near Jigjiga, one perhaps rather to the east, but two *in situ*, one 'from apparently a small intrusive sill' in the pass, and another with sandstones or grits 'on the road to Fantalli and Harrar.' Also associated with grits was a basalt from the hill close to the east side of the camp at Garsa (Karsa). Similar rocks were taken 'from a dyke in the valley west of Colluby,' where the expedition camped, and from the pass high up before getting to camp, and some distance west at the Laga-Hardim Camp, both in the lower and the upper series of rocks. Basalts were collected from the second brook-cutting going from camp into Addis Abbeba, from between that town and Akaki ('exposed among softer tuff-rock'), and *in situ* at Galanda Lotha towards Mount Saquala.

A slice cut from a dark-grey finely-speckled basalt from Tsingari contains a few microporphyritic felspars, partly corroded and

[1] Geol. Mag. 1901, p. 411.

[2] 'Beiträge zur geol. Kenntniss des östlichen Afrika' pt. ii, Denkschr. d. k. Akad. Wissensch. Wien, vol. lviii (1891) pl. ii, fig. 4.

[3] See p. 303.

exhibiting rather micropegmatitic inclusions, and one interesting crystal of augite. It is large ($\frac{3}{10}$ inch long), irregular at the edge as if corroded, and encloses numerous clear, small grains of augite like a micropegmatite, in the arrangement of which a slight orientation along what may be cleavage-planes can be traced. The explanation is difficult, but, although local melting and recrystallization seem possible, it is perhaps more likely that, after the small augites had formed, the large crystal developed around them, spreading until solidification of the neighbouring groundmass prevented further growth and produced an irregular outline.

In a dark slaty-grey basalt from Chellahah the groundmass contains a little glass, and microlithic felspars exhibiting a fluxional arrangement. The rock from a hill near Mendi is compact, subophitic, but with small amygdales.

(iii) Glassy basalts include a pebble from a brook towards Errer, one specimen from near Hirna (although this might be a basic andesite), others from the hill east of Laga-Hardim Camp (including one or two from the upper series), from Fantalli, from the surface between Akaki and Addis Abbeba, and from Gatama. These rocks are mostly blackish, compact or finely glittering. The siena-brown glass contains imperfect skeleton-crystals and granules of opacite which render the matrix confusedly dusky. It encloses greenish palagonitic patches and some small crystals. Two or three specimens are purplish, and some vesicular, others containing porphyritic crystals.

(iv) Vesicular or scoriaceous rocks (doubtless basalts).—The most scoriaceous are from the talus near Addi Adeya, the greatest number from the hill east of the camp at Laga Hardim, many from the upper series of rocks. Two others are from near the Hawash River, two from Fantalli, and one from Toki.

(2) Phonolites and Allied Rocks.

Rocks containing nepheline occur at two localities.[1] They are found at Garsa, about long. 42° E., beyond Lake Haramaia in the South-East of Abyssinia, with sandstones and grits, and near Bilo (about long. 37° E.), much farther west on the Gibbe River, connected with the extensive area of Southern Abyssinia which is occupied almost wholly by volcanic rocks. The Saquala rocks, from south of Addis Abbeba, are probably allied to the phonolites.

Two specimens of a blackish, almost glassy-looking rock from Bilo (or near that place), weathered brown, contain large ($\frac{1}{2}$-inch) cleaved glassy crystals. These sometimes are singly twinned, with two cleavages at about right angles, sparsely cracked, extinguish straight, have low double refraction, and probably are sanidine; although a possible twinning like that of anorthoclase is very faintly

[1] Compare also A. Rosiwal, 'Beitr. geol. Kennt. des östl. Afr.' pt. ii, Denkschr. k. Akad. Wissensch. Wien, vol. lviii (1891) p. 465; J. W. Gregory, Quart. Journ. Geol. Soc. vol. lvi (1900) p. 205; & G. T. Prior, Min. Mag. vol. xii (1900) p. 255.

represented in one or two crystals. One or two others, rounded in outline, apparently without cleavage, containing minute fluid enclosures, exhibit an all-round extinction. This suggested the possibility of leucite, but the characteristic structure is wanting, and the grains might be transverse sections of a hexagonal crystal like nepheline. The porphyritic crystals sometimes enclose grains of augite or patches of the groundmass. The groundmass is micro-ophitic, perhaps with a little residual glass, with lath-shaped felspars often singly twinned, and nepheline in rectangular and hexagonal sections. A pale filmy hornblende exhibits characteristic cleavage, especially well shown in one crystal. The pleochroism in this (and in one or two which extinguish at about 40°, and enclose opaque blackish grains) is from pale chestnut or reddish-brown to very pale fawn-colour. In other (mostly minute) crystals, often extinguishing at 18° or 20°, it is from chestnut-brown to pale apple-green. The hornblende may be a common species, but it exhibits a resemblance to the catophorite of Brœgger from Grussletten.[1] Dark-brown or red-brown crystals, often opaque in the centre, are possibly cossyrite.[2] Another mineral, having a peculiar pleochroism to a deep greenish-blue, often occurs in a small patch clustered around nepheline or felspar, and although perhaps not the most typical example, is doubtless riebeckite,[3] possibly with some ægirine, and the slice contains a pale-green augite.

A rock obtained just before reaching Bilo, dark-grey, with a somewhat greasy lustre, shows a slight linear streaking. The small, crowded, colourless crystals in the groundmass are mostly nepheline, exhibiting hexagonal and rectangular sections. Some microchemical tests gave further corroboration of the identification of this mineral. The rock-slice was readily etched by hydrochloric acid (in $1\frac{1}{2}$ minutes), and stained with malachite-green. The solution in hydrochloric acid deposited many small cubes of sodium-chloride, and in hydrofluosilicic acid, good crystals of sodium-fluosilicate. Lath-shaped felspars, less sharply defined, and a small pyroxene occur, resembling minerals found in the next-described rock. Pale-brown films, sometimes hexagonal, with aggregate polarization, are possibly mica.

A speckled greyish rock from Bilo exhibits close wavy shimmering surfaces. In the microscope-slice, two generations of felspar-crystals occur, both numerous, distinctly orientated, probably sanidine and anorthoclase, the latter often exhibiting an undulose extinction, both in this and in the preceding rock. Some of the

[1] See 'Die Eruptivgesteine des Kristianiagebietes: I. Die Gesteine der Grorudit-Tinguait Serie,' Vidensk. Skrift. 1894, No. 4, pp. 27–39; and Rosenbusch [transl. Iddings] 'Microscop. Physiogr.' 4th ed. (1898) App. p. 352 *c*.

[2] This identification was suggested by Mr. G. T. Prior. I have to thank Mr. L. Fletcher for kind permission to study slices in the collection at the British Museum (Natural History). I owe many thanks to Mr. Prior for selecting some of these, for looking at my slides, and for giving me on several a confirmatory opinion.

[3] I have to thank Prof. Bonney for the loan of slides in which I was able to study typical riebeckite, some in the Mynydd-Mawr rock, and a still richer development in a Socotra specimen.

larger crystals, rather scattered, not quite complete in outline, exhibit straight or all-round extinction, and are probably nepheline. In some of these a narrow irregular margin around the enclosed crystal is a secondary product formed of an isotropic mineral, probably sodalite.[1] The pyroxene which fits in between the other constituents, and sometimes fringes the nepheline, is mainly ægirine or an ægirine-augite. As in the last rock, much of this is somewhat platy, with extinction about 30°, pleochroic from green to brownish with the usual tints, and rather resembles ægirine-augite. Iron-oxide is present, and one felspar encloses a few very minute zircons. A microscopic vein is partly filled with what is possibly aragonite. The rock is a phonolite with fluxional structure, and somewhat resembles the sölvsbergite from Edda Gijorgis (Central Abyssinia) brought by Dr. Sadebeck.[2]

Among the 'rocks with a dip of 80° to the north-east, obtained in ascending the hill close to the east side of the camp at Garsa,' partly grits and sandstones, are pale fawn-coloured or whitish felsitic-looking rocks with blackish speckled patches. The ground-mass (which possibly includes nepheline) passes at places into a micropegmatitic intergrowth with a greenish or brownish mineral forming moss-like groups. The greenish mineral includes riebeckite (pleochroic from deep blue to greenish and pale yellow, with well-marked cleavage and low extinction), and associated with this some ægirine (pleochroic from grass-green to greenish-yellow, with low extinction-angle and strong double refraction). The brown mineral, although it may partly represent a cossyrite, is, much of it, doubtless an alteration-product, and iron-oxide and small epidote are present. Microporphyritic, generally oblong, crystals occur, from the edge of which radial tufts grow inward, certainly a secondary development, possibly due to subsequent heating by intrusion of an igneous magma. The crystals sometimes extinguish straight, and, although the secondary replacement renders the identification of many uncertain, some at least are probably nepheline; and the rock was readily etched with hydrochloric acid, especially the microporphyritic crystals, and these most strongly along the margin. Also, with hydrofluosilicic acid, minute hexagonal crystals of sodium-fluosilicate were formed in fair quantities.[3] The rock somewhat resembles an ægirine-tinguaite from Hot Springs (Arkansas), a slice of which is in the collection at the British Museum (Natural History).

The rocks next described, although apparently not containing nepheline, are certainly allied to the phonolites.

Mount Saquala and its neighbourhood.—A dark-grey rock in two specimens from this mountain, contains small porphyritic crystals of felspar (sanidine and anorthoclase). Other microporphyritic crystals (highly refractive, and ironstained along

[1] I have to thank Prof. Bonney for the loan of additional slides containing this mineral for comparison.

[2] Described by Mr. Prior in Min. Mag. vol. xii (1900) p. 265 & pl. iii, fig. 4.

[3] See Rosenbusch [transl. Iddings] 4th ed. (1898) pl. x, fig. 5.

the edges and cracks) consist of a green, slightly-pleochroic, well-cleaved augite, and of a yellowish mineral, probably olivine, enclosing clear belonites. The groundmass consists largely of small rectangular crystals like nepheline, but, as no hexagonal sections can be seen, they are probably orthoclase (or anorthoclase). These are embedded in a possibly quartzose base. A greenish and a brownish mineral, intercrystallized sometimes in a micro-ophitic manner, form mainly an ill-defined network with rounded meshes. The green mineral, pleochroic from bluish-green, extinguishing sometimes at 3°, is doubtless riebeckite, and the brown seems partly an alteration-product; but some crystals, brownish or red-brown, opaque within, and sometimes pleochroic almost to black, are very probably cossyrite. The rock has a likeness to some containing nepheline, and might be a soda-bearing augite-felsite or porphyrite.[1] The two specimens labelled, one from the summit, the other from the western edge of the crater, are alike, and thus afford a presumption that they represent the general character of at least part of the eruptive rock of this volcano.

Thus several types of phonolites and their allies occur in the collection. One rock from near Bilo approaches the sölvsbergite of Brœgger. A second and a third rock, from the same general locality, are rather tinguaites. One contains very abundant scattered nepheline, the other contains porphyritic felspars and riebeckite. The rock from Garsa, with moss-like patches, including riebeckite, is a possible tinguaite, and resembles the types from Adowa and Axum. Lastly, the rocks from the crater and summit of the volcanic mountain Saquala are closely allied, although containing apparently no nepheline, resembling the 'phonolytic trachytes' described by Mr. Prior, from the 'Rift-Valley' district.[2]

A pale purplish-grey rock with close whitish bands, from Balchi Hill, resembling a porphyrite in appearance, contains porphyritic plagioclase within a minutely-microcrystalline, somewhat orientated groundmass. Although hexagonal sections are rare, some are found, and nepheline is probably present. Some very small crystals of a pyroxene occur, also iron-oxide; and a few minute crystals may represent nosean, although the lines of small black spots do not show the usual 'grating' arrangement, but are inclined to be parallel. The rock is certainly fluxional; it can only be doubtfully placed near the phonolites.

(3) Andesites and Porphyrites.

Three rocks from the bed of the Hawash River, within 2 miles of the base of Mount Saquala, westward of it, are grey and compact. The glassy groundmass shows a fluidal structure, and

[1] I have to offer additional thanks to Mr. Prior for presenting me with an advance-copy of his article on the Petrology of British East Africa, just as I had completed this paper, and allowing me to compare some of the slices described by him. The rock of Mount Saquala much resembles some of those classed as phonolitic trachytes or quartz-trachytes. Thus it seems allied to the earlier phonolitic lavas of the Kapte Plain, rather than to the more basic nepheline-rocks of the active volcanoes of Doenyo Ngai and Mount Elgon.

[2] Min. Mag. vol. xiii (1903) p. 228.

contains small porphyritic crystals (felspar, hornblende) and included fragments of rock like small rounded lapilli. Although these specimens appear to be fluxional andesites, they might possibly represent some of the phonolitic series.

Of two porphyrites obtained near Bilo, one, a rich red compact rock with porphyritic crystals of felspar, has a very fine-grained microlithic groundmass, coloured by iron-oxide. The second, from the hill towards Abbra Gibbe, is rather felsitic in aspect, and the groundmass is found to consist of narrow felspar-crystals with fluidal orientation. A purplish-grey porphyrite, somewhat similar, comes from east of Garsa Camp.

Several andesites occur in the hill east of Laga-Hardim Camp, in the lower series of rocks. A slice from one of these contains patches (probably due to flow-brecciation) in which a roughly-reticulate arrangement is rather like that in some nepheline-rocks, where ægirine is grouped to form the lines of the network.[1]

The other andesites from this locality often enclose small scoriaceous fragments and porphyritic crystals, sometimes broken or worn. They generally exhibit a fluxional structure, and one of them, from near the Hawash River, is traversed by platy jointing; another, from the Fantalli Hills, is dark, even blackish in the hand-specimen.

Some pale-brown rocks from Chaffi Dunsa contain many angular fragments of crystals and of rocks, felsite or porphyrite. The groundmass consists of wavy patches rich in secondary kaolin, and of streaks of brown glass, so the rock is probably a flow-brecciated andesite, and not a tuff. Several andesites from near Addis Abbeba (the southern end) resemble those from near Laga Hardim.

Trachytes (?).—Two rocks at the back of the Residency at Addis Abbeba are vesicular, yellow to brick-red in colour. One of them exhibiting marked fluidal structure includes green microliths and incipient crystals generally squarish in section, suggestive of a potash-felspar, as if the rock might belong to the sanidine-trachytes. The glassy groundmass of two specimens contains fragments doubtless caught up in flowing. A specimen from Laga Hardim is compact, and of a dull olive-green. The colourless glassy base is crowded with minute granular epidote and pyroxene (?), and the fragments enclosed are of felsite, felspar, and glassy basalt. A rather earthy-looking greenish rock from the Fantalli Hills exhibits flow-structure, and contains a few fragments.

Claystones.—Several claystones, probably decomposed andesites or trachytes, occurred at Addis Abbeba and at the Akaki Gorge.

Obsidian.—A small flake of black obsidian, apparently artificially chipped, was found not far from Jigjiga (with a flake of chert and some quartz) near the place where Mr. H. W. Seton Karr obtained Palæolithic implements.[2]

[1] Compare that in the Saquala rock, p. 300.
[2] Journ. Anthropol. Inst. vol. xxv (1896) p. 271.

Pumiceous tuffs.—These are fine-grained, dusty or sandy-looking rocks. Three are from east of Laga Hardim from the lower series, two from the Akaki Gorge, and two from near Bilo. In all, the powdered material consists almost wholly of colourless glass-chips, generally vesicular and pumiceous, with felspathic material in one specimen.

IV. Sedimentary Rocks.

(*a*) Arenaceous Rocks.

Sandstones and sands occurred between the coast and the Abyssinian frontier, and in the south-eastern part of that country. One greyish-banded quartzite, with spots coloured by hæmatite, collected east of Garsa, resembles rocks of a rather early geological age.

Quartzose sandstones similar to those of late Mesozoic age include one from Dobeia, not far from the coast, many at and near Jigjiga Pass, and between that frontier-pass and Chercher. In the last-named area, most of the ferruginous sandstones and grits (so characteristic of many African collections) were obtained. In all, the quartz-grains often interlock, forming almost a quartzite, and the secondary zone along their edge is in one rock partly opaline silica. In another, lines curved like perlitic structure, or crossing at right-angles, may have been caused by heat from neighbouring volcanic masses.

The action of blown sand is sometimes exhibited, as in a loose fragment from above Hargaisa, found by Lord Lovat. This specimen of a banded, slightly calcareous sandstone is bluntly conical, but rounded, and is worn into ridges along the alternating bands.

The compact ferruginous sandstones (almost quartzites) are purple or reddish-brown, with white felspar-speckling, banded, and often exhibit current-bedding. Infiltrating water has sometimes formed an 'iron-pan' or concretions, which in one of the coarser grits occur as rounded nodules with concentric structure.

One fine-grained red rock from near Lake Chercher, might be a rotten tuff, but is possibly only a clay.

(*b*) Calcareous Rocks (and Organic Rocks).

Crystalline limestone.—Two fragments of a white, coarse crystalline limestone 'from among granite . . . between Errer and Harrar' contain flakes, three-tenths of an inch long, of a bright-brown pleochroic phlogopite.

Dolomites.—South-west of Berbera, a whitish subcrystalline dolomite occurs at a distance of about 15 miles, and a minutely granular dolomite at about 24 miles. The latter, a 'vein in a granitoid rock,' contains angular fragments of quartz, plagioclase, green hornblende, and limestone, and a few obscure organisms. Other granular dolomites, from near the Jigjiga Pass and Fyambiro, consisting of minute rhombohedra, exhibit inclusions like those in

the 'vein' described above, but chiefly of quartz. One of three specimens from south of Laga-Hardim Camp exhibits oolitic grains within a subcrystalline matrix. Two 'chalky-looking rocks,' one not far from Addi Adeya with volcanic rocks, the other near Jummat 'with granite,' may be similar rock decomposed; and a friable specimen, effervescing briskly, and consisting of minute rhombohedra of calcite, is probably a decomposed limestone.

Brecciated or concretionary limestones.—In one brecciated-looking limestone a pale brownish matrix contains darker brown, imperfectly-rounded fragments. A marked black rim gives them a likeness to pebbles, and rounded quartz-grains or pebbles are similarly embedded. Some resemblance, however, to tufaceous or concretionary limestone suggests the action of infiltrating water. The black margin of the fragments is undoubtedly due to secondary deposition, since it extends along wavy planes in the rock and along joints or cracks. Five typical specimens have been brought, all from between Berbera and the Abyssinian frontier. One from the rock forming the hill at Dobeia, exhibits a weathered surface, coarsely grooved and pitted (? by sand-blast), and encloses small fragments of quartz and of dolomite. Of two rocks from the camp at Jefa Medr, one contains larger fragments ($\frac{1}{2}$ to $\frac{3}{4}$ inch), the other exhibits wavy lines and narrow veins like those of septaria. In a compact rock 'protruding from the surface at many points' towards Jigjiga, are fragments of stony limestone. The margin of these is marked by concentric streaks or lines, which consist of limonite and veins of dolomite. The cracking or jointing of these limestones (along curving or rectangular lines) may be possibly due to heating by the sun's rays. Subsequently infiltration occurred, and secondary deposition generally of iron-oxide or of dolomite.

A compact limestone from the hill at Jefa Medr has apparently undergone subsequent brecciation, and may be possibly related to the above.

Limestones with organisms.—Some of the foraminiferal limestones 'about 15 miles south-west of Berbera, forming the main mass of the hill,' are compact, pinkish with whitish patches, and much dolomitized. They contain the alga *Lithothamnion* well preserved, and *Amphistegina (?)*. A second type is hard, compact, whitish or drab-coloured, often breaking with subconchoidal fracture (resembling some described in 1888 also from Somaliland [1]). Near Jigjiga Pass this rock contains *Globigerina*, chambered Rotaline foraminifera, *Textularia*, *Orbulina*, and *Lagena*. To the south of Laga Hardim a similar rock exhibits *Miliola* and *Textularia*. Several specimens from Burka to Hirna include cylindrical branching structures ($\frac{1}{2}$ inch across) difficult to determine, and in the microscopic slice one or two specimens of a *Dactylopora (?)*. The sections of the larger structures suggested some resemblance to a sponge; and Dr. G. J. Hinde most kindly undertook a careful examination of

[1] 'On some Rock-Specimens from Somaliland' Geol. Mag. 1888, pp. 417, 418.

the specimens. He reports that there is not a trace of a spicule to be seen, and consequently it cannot be decided whether the organism is a calcisponge or not. The fine-grained muddy groundmass, speckled with small crystalline grains of dolomite, contains some minute organisms. The lithological and fossil contents of these limestones make it probable that they are of Cretaceo-Eocene age, or possibly Miocene.[1]

One limestone 'near the summit of the Pass' from Jigjiga to Abyssinia, found 'in enormous blocks, doubtless fallen from above,' is white or cream-coloured. It is crowded with a gasteropod ($\frac{1}{2}$ to $\frac{3}{4}$ inch long), doubtless a *Turritella*,[2] and in the cut slice a few fragments of a polyzoan occur. Calcite-crystals line the chambers of the *Turritella*, and border small fragments and some oolitic grains.

Another limestone, generally fine-grained and muddy, is crowded with organic fragments, which stand out on a weathered surface. The specimen from the hill south of the camp, near Colluby, contains *Miliola*, *Textularia*, *Calcarina (?)*, and some oolitic grains.

The rock at the 'Pass between Colluby and Galimala (?) beneath basalt' furnishes a slightly-brecciated slice, with a cement of clear crystalline dolomite. It encloses brownish oolitic grains and numerous fragments of *Lithothamnion*, of an echinoderm-plate or ossicle, and a polyzoan (?).

Chert.—A small flake (probably artificial) of whitish chalcedonic chert was brought from between Jigjiga and Sobolo or Jefa Medr. It is crowded with sponge-spicules, which are embedded in pale brownish opaline silica, and are often chalcedonized.

V. Specimens brought back by Lord Lovat.[3]

These were taken chiefly from four localities. The journey was made from Addis Abbeba (about lat. 9° N.) to Dessieh (about lat. 11° N.), and the return was by a kind of loop-line to the east.

(1) Ahiafedge.—Along the gorge, a section exposed below the soil (6 feet) of the plateau showed a felstone, 10 to 30 feet thick, intercalated between two layers of basalt. Then two successive shoulders, projecting into the valley, consist mainly of a sheet of basalt 200 feet thick. The rock is dark-brown, sometimes 'flaky,' or containing small amygdales or pinhole-cavities filled with a green or brown serpentinous product. A 'weathered rock 40 feet thick' was passed, apparently a gritty tuff, and successive sheets of basalt, one with vesicles partly filled by analcime, one columnar and vesicular, one probably spheroidal. The most interesting specimen is described as 10 feet of 'coal-like rock,' hard and splintery. The fragment is cracked and brittle, and contains a few amygdales. It is a brown glass, with a flow-structure slightly indicated by small

[1] See Geol. Mag. 1888, p. 418.

[2] See Mayer-Eymar in K. A. von Zittel's 'Beiträge zur Geol. u. Palæont. der Libyschen Wüste, &c.' Palæontographica, vol. xxx (1883) pl. xxiii.

[3] I have been unable to identify three localities from which specimens were brought by Lord Lovat, but the rocks, like those of Mount Yoel (Yoil), were mainly basalts.

belonites, and contains grains of iron-oxide and a few crystals of augite and of felspar, some much corroded, others perfect with albite-twinning. The perlitic cracks in the glass are narrow, and sometimes polarize brightly. The specific gravity (tested on two occasions by a Walker's balance) was found to be between 2·33 and 2·38, the variation being probably due to the cracked and splintery character of the specimen. Thus the rock seems to be an andesitic pitchstone rather than a tachylyte. Other basalts occur (one layer 100 feet thick), then a bed of white quartz-sand, and one of a slightly quartzose red clay, which may be a basaltic tuff or possibly an ordinary sediment.

(2) Mount Yoel consists largely of igneous rocks, but furnishes one specimen of a white quartz-sand. Decomposed felstones are represented by two rocks at the foot of the mountain (one on the south side). In one fresher porphyrite, just above the plain on the Baramidia (?) side, the groundmass consists mainly of lath-shaped plagioclase, with needles and patches of iron-oxide. A black basalt with a ferruginous glass comes from the same side. A red rotten rock may be also either a basalt or a basic ash. A compact, jointed basalt comes from the summit.

(3) Gibbe Hill is formed of volcanic rocks, the specimens being basalts, sometimes glassy, often vesicular or amygdaloidal. One of these, rather rotten, forms a 'bed near the summit.' Another dark-red weathered rock becomes disintegrated and veined, with development (in amygdales and veins) of crystals, clear, colourless, often with penetration-twins. These at first sight appear to be cubic, but are really rhombohedral, with low double refraction, and I would refer them to chabazite.

(4) Between Gewaba and Allali(?).—These rocks are compact basalts, microcrystalline (with a second pyroxene or a little altered olivine) or glassy, sometimes spheroidal, as is shown by a flake which has shelled off one specimen. The surface of one fragment is smoothed and ridged, as if worn by blown sand.

(5) Blocks in river-bed, Djemma(?).—One is a dull black rock, compact, but jointed and cracked. The finely-speckled glass contains a few small felspars and augite-crystals, and exhibits perlitic cracks as ill-defined brownish lines, a structure not very frequently found in a magma-basalt. A second block, blackish and compact, but crowded with spherical amygdales, is found to consist of a brown glass, with abundant granular iron-oxide, crossed by perlitic cracks, which are whitish or colourless lines, polarizing brightly. It is doubtless a very basic andesite. A similar rock comes from Gewaba (?), from the lowest exposed bed.

(6) Some water from a hot spring south-west of Addis Abbeba (collected on February 21st, 1899) was brought back. The subjoined analysis was made by Mr. W. L. Alton in the Chemical Laboratory of University College (London), through the kindness of Sir William Ramsay, to both of whom I am greatly indebted :—

Total solid residue = 2·5806 grammes per litre.

	Per cent.
Carbon-dioxide	14·42
Iron-peroxide	1·21
Lime	1·21
Magnesia	2·43
Soda	42·18
Sulphuric acid	5·18
Silica	4·66
Chlorine (by difference)	28·71
	100·00

EXPLANATION OF PLATE XXI.

Map of part of Southern Abyssinia, on the scale of about 70 miles to the inch.

The topography is copied, by kind permission, from the map printed for use at the meeting of the Royal Geographical Society on December 11th, 1899.

The exact position and the area of the outcrops of the rocks can only be roughly indicated, but the general succession of the localities is taken from the dates on the labels accompanying the specimens.

Discussion.

The President spoke of the interest of the results worked out by the Authoress, and of the clearness with which they had been laid before the meeting by Prof. Bonney. Most of the rocks described appeared to agree remarkably with the other African types usually classed as Tertiary, but a few seemed to suggest those of the Abyssinian plateau associated with the Jurassic limestones of that region. It would be very interesting to know how the widespread Tertiary igneous rocks of Africa were related to, or differed from, those of the earlier geological epochs.

Mr. Prior welcomed the paper as affording still further proof of the wonderful uniformity in type of the more or less recent volcanic rocks of the African continent. Members of the remarkable alkali-rich rock-series, to which the eruptive rocks of the Great Rift-Valley mainly belonged, were widely distributed over Africa from the island of Pantelleria in the north to Madagascar in the south, as well as in the Canary Islands, the Azores, and other islands off the western coast. This constancy in type was almost sufficient to constitute of Africa an immense petrographical province.

Prof. Judd congratulated the Authoress on her discovery of the wide range of rocks derived from an alkaline magma. Such rocks, indeed, were now known to be widely distributed, and recent discoveries in Australia and New Zealand had furnished additional evidence on this point.

Prof. Bonney, in reply to the President's question, said that he believed that the district around and to the north of Addis Abeba formed the southern end of the great Abyssinian plateau, but that no evidence had been furnished as to the geological age of the basalts of which this part was so largely composed.

XXI.

ERN
80
L A
N
Takatsi
ts.
R
Fossils:
minifera
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cks
Mt.
nagash
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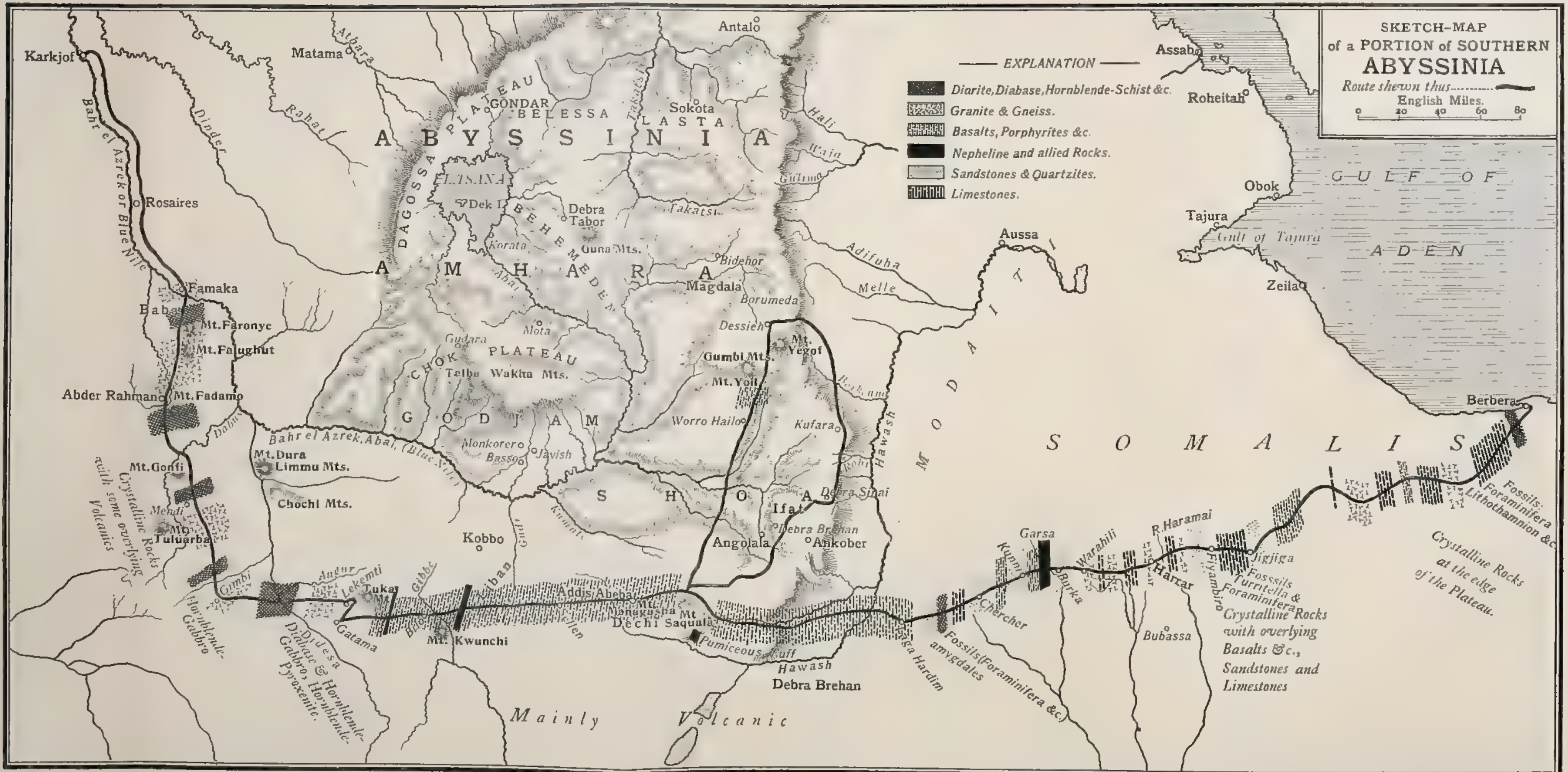
SKETCH-MAP
of a PORTION of SOUTHERN
ABYSSINIA
Route shewn thus
English Miles.
0 20 40 60 80
EXPLANATION
Diorite, Diabase, Hornblende-Schist &c.
Granite & Gneiss.
Basalts, Porphyrites &c.
Nepheline and allied Rocks.
Sandstones & Quartzites.
Limestones.
ABYSSINIA
AMHARA
GODJAM
SHOA
MODAITI
SOMALIS
GULF OF ADEN
Gulf of Tajura
Mainly Volcanic
Karkjof
Matama
Antalo
Assab
Roheitah
Obok
Tajura
Zeila
Aussa
Berbera
Rosaires
Famaka
Mt. Faronye
Mt. Falughut
Abder Rahman
Mt. Fadamo
Mt. Gonfi
Mt. Tuluarba
Crystalline Rocks with some overlying Volcanics
Hornblende-Gabbro
Diorite & Hornblende-Gabbro, Hornblende-Pyroxenite.
Gondar
Belessa
Lasta
Sokota
Dagossa Plateau
Debra Tabor
Guna Mts.
Magdala
Bidehor
Borumeda
Dessieh
Mt. Yegof
Gumbi Mts.
Mt. Yoit
Worro Hailo
Kufara
Chok Plateau
Telba Wakita Mts.
Mota
Monkorero
Basso
Javish
Mt. Dura
Limmu Mts.
Chochi Mts.
Kobbo
Ifat
Debra Sinai
Debra Brehan
Angolala
Ankober
Addis Abeba
Mt. Managusha
Dechi
Mt. Saquala
Pumiceous Tuff
Hawash
Debra Brehan
Tuka Mt.
Lekemti
Gatama
Mt. Kwunchi
Bahr el Azrek or Blue Nile
Bahr el Azrek, Abai, (Blue Nile)
Dinder
Rahat
Athara
Takatsi
Hali
Adifuha
Melle
Hawash
Garsa
Kunni
Burka
Chercher
Warahili
R. Haramai
Harrar
Fiyambiro
Jigjiga
Bubassa
Fossils (Foraminifera &c.) amygdales
Fosssils Turritella & Foraminifera
Crystalline Rocks with overlying Basalts &c., Sandstones and Limestones
Crystalline Rocks at the edge of the Plateau.
Fossils: Foraminifera Lithothamnion &c.

22. Note *on the* Occurrence *of* Keisley Limestone-Pebbles *in the* Red Sandstone-Rocks *of* Peel (Isle of Man). By E. Leonard Gill, Esq., B.Sc., Curator of the Natural History Museum at Newcastle-upon-Tyne. (Communicated by Prof. W. Boyd Dawkins, M.A., D.Sc., F.R.S., F.G.S. Read April 8th, 1903.)

In his recent paper on 'The Red Sandstone-Rocks of Peel,'[1] Prof. Boyd Dawkins mentions a rock which occurs in a derived form in one of the conglomerates of the Peel Series, and has been identified with the Keisley Limestone. When Prof. Boyd Dawkins was preparing the paper quoted above, he entrusted to me the examination of the pebbles of the rock in question; and as the resulting identification possesses an interest apart from the main issues of his own work, he has kindly offered me the opportunity of giving a separate account of it. The following notes, therefore, contain a brief description of the rock and its fossil contents, with the grounds for believing it to be identical with the Keisley Limestone.

The pebbles which formed the material for the investigation were collected by Prof. Boyd Dawkins from the conglomerates forming the coast-line at Whitestrand, near Peel (Isle of Man).[2] They are composed of a coarsely-crystalline limestone, greyish-white in ground-colour, and as a rule thickly mottled with pink: agreeing, in fact, very closely with those beds of the Keisley Limestone which Mr. F. R. Cowper Reed, M.A., F.G.S., speaking of their lithology in his exhaustive paper on that group,[3] describes as Type 3. The amount of this limestone available for examination was not great; and at first, as no fossils more distinctive than ostracods and some small and indefinite brachiopods had been met with, it was thought, on the strength of other fragments with which it was associated in the conglomerate, that this rock was derived from the Carboniferous Limestone. On breaking up the pebbles, however, the discovery of several heads of *Illænus Bowmani* and shells of *Plectambonites quinquecostata* proved it to be of Ordovician, and probably of Bala, age. My attention was then directed by Mr. P. F. Kendall, F.G.S., to Mr. Cowper Reed's papers on 'The Fauna of the Keisley Limestone,'[4] and a striking correspondence in several particulars was at once evident. The three most characteristic fossils in the pebbles collected by Prof. Boyd Dawkins were

> *Plectambonites quinquecostata*;
> A small *Euomphalus*-like gasteropod; and
> *Illænus Bowmani.*

Of these, the *Plectambonites* is found commonly enough in the Keisley Limestone; the *Euomphalus*-like shell appeared to agree exactly

[1] Quart. Journ. Geol. Soc. vol. lviii (1902) p. 642.
[2] *Ibid.* p. 641, Table. [3] *Ibid.* vol. liii (1897) p. 100.
[4] *Ibid.* vol. lii (1896) p. 407, & vol. liii (1897) p. 67.

with *Platyceras verisimile*, described and figured by Mr. Cowper Reed [1] as a new species from the Keisley Limestone itself; and the heads of *Illænus Bowmani* were of a type that was found by Mr. Reed to be abundant in the Keisley Limestone, and was spoken of by him under the name of *I. Bowmani*, var. *brevicapitatus*.

Prof. Boyd Dawkins, at my request, submitted specimens of these three fossils to Mr. Reed, who confirmed my identification of them and the conclusion drawn from it, namely, that the pebbles were in all probability derived from beds of Keisley Limestone. I have since then, through the kindness of Mr. Reed and the staff of the Woodwardian Museum (Cambridge), been able to compare the fossils from the Peel pebbles with the series of Keisley-Limestone fossils at Cambridge which formed the main portion of the material for Mr. Reed's work.

Owing to the fact that it was only possible to examine so small a bulk of the limestone, the actual number of specimens of the fossils found in it was by no means large, and it cannot be supposed that they make any approach to representing a complete fauna of the beds from which the pebbles were derived. So far as they go, however, it may be said that they not only all belong to species which are found in the Keisley Limestone,[2] but that they form a group which would be a characteristic small selection of fossils from that horizon. The following list shows all that I have obtained.

Trilobita.

Illænus Bowmani, Salter. The three well-preserved heads of this trilobite which I have met with are all of the form described by Mr. Cowper Reed [3] as *Illænus Bowmani*, var. *brevicapitatus*. In one of them the striations extend with great regularity from the front-margin to the summit of the glabella; behind this point the outer test is missing, so that it is impossible to see whether the ornamentation was continued, as seems likely, to join the occipital group of lines. A small pygidium, probably belonging to this species, has also been found; but I have seen no recognizable remains of any other trilobite.

Ostracoda.

Many pieces of the limestone contain large numbers of ostracod-tests. It is not easy to be sure of any identification of these; but the majority appear to agree entirely with Prof. T. Rupert Jones's figures [4] of *Primitia Maccoyii*, Salter, which Mr. Reed mentions as the only form abundant at Keisley.

Brachiopoda.

Orthis calligramma, Dalman. One small valve and part of a larger one.
Orthis testudinaria, Dalman. Two small shells.
Orthis biforata, Schlotheim. One small ventral valve, which agrees externally with this species.

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[1] Quart. Journ. Geol. Soc. vol. liii (1897) p. 79 & pl. vi, fig. 7.
[2] See list given by Mr. Cowper Reed in Quart. Journ. Geol. Soc. vol. liii (1897) p. 85.
[3] Quart. Journ. Geol. Soc. vol. lii (1896) p. 412 & pl. xx, fig. 4.
[4] Ann. & Mag. Nat. Hist. ser. 4, vol. ii (1868) p. 55 & pl. vii.

Orthis sp. Part of a larger shell, different from the above, but too imperfect for identification.

Rafinesquina deltoidea, Dalman. Two or three small shells, with scarcely a trace of concentric wrinkling: this is mentioned by M'Coy [1] as characteristic of some of the Coniston specimens of this form.

Plectambonites quinquecostata, M'Coy. Several well-preserved shells.

Atrypa expansa, Lindström. Several of various sizes, from a quarter to three-quarters of an inch in diameter.

Hyatella Portlockiana, Davidson. Two shells, which agreed with examples of this species in the Woodwardian Museum.

Dayia pentagonalis, Reed. One very small valve, which appeared to agree with young examples of this species in the Woodwardian Museum; it is not, however, distinct enough to base any conclusion upon it.

Mollusca.

Platyceras verisimile, Reed. Four well-preserved specimens of this gasteropod have been met with. It was described by Mr. Cowper Reed [2] from the Keisley Limestone, and is not known to occur in any other beds.

Echinodermata.

The limestone of many of the pebbles is crowded with crinoid-stems, which present in cross-section considerable variety in form and size, and probably belong to several different species.

Actinozoa.

Stenopora fibrosa, Goldfuss [? Monticuliporoid]. Some sections which Prof. Boyd Dawkins had had prepared showed good specimens of this coral.

The foregoing list shows that the group of fossils yielded by the pebbles, though it may represent only very incompletely the fauna of the parent limestone, is yet sufficient to prove that this limestone was of the age of the Bala Beds; while its identity with the Keisley Limestone in particular is strongly indicated by the presence of several forms believed to be peculiar to that division, and is further supported by the evidence of the remainder of the fossils, and by the lithological characters of the rock.

In view of the isolated position of the Keisley Limestone in Westmoreland, the discovery in a new locality of a rock identical with it, even though it be only in a derived form, is of considerable interest. It is not, of course, possible to say exactly what this identity amounts to; whether, in fact, the pebbles in the Peel conglomerate are fragments of the actual limestone-mass of Keisley, or have been derived from corresponding beds in the more immediate neighbourhood of their present resting-place. It seems hardly likely, however, that they should have originated from so distant a locality as the Cross-Fell district, especially as Prof. Boyd Dawkins [3] has proved a local source for the other varieties of pebbles found with them in the conglomerate; and on this view, their

[1] Quoted by Davidson, 'Monogr. Brit. Foss. Brach.' vol. iii (1871) p. 293 (Palæont. Soc. vol. xxiv).

[2] Quart. Journ. Geol. Soc. vol. liii (1897) p. 79 & pl. vi, fig. 7.

[3] *Ibid.* vol. lviii (1902) p. 641.

occurrence here, in the Isle of Man, suggests the existence in later Palæozoic times of an intervening link between the limestone-masses of Keisley and the Chair of Kildare, which Mr. Cowper Reed has already shown to be palæontologically so closely related.

Discussion.

By permission of the Chairman (Mr. Teall), the Secretary read the following remarks received from Mr. P. F. Kendall:—

'I wish to commend this paper to the Fellows as a most careful and conscientious piece of work, and at the same time to say how unfortunate I deem it that the Author is unable to present it in person. He identified some of the fossils as Ordovician species, at a time when all observers were disposed to refer the limestone-pebbles to the Carboniferous Series. I chanced to see some of the specimens, and immediately recognized the exact resemblance between the matrix and the Keisley Limestone, an identification which is now fully confirmed.

'It is much to be regretted that the Author has not undertaken the re-examination of the other fossiliferous pebbles from the Peel Sandstones, for I think that it is in the highest degree probable that the alleged Carboniferous species will be found to be actually Ordovician; the matrix seems to be of the Keisley type in all cases.'

23. *On the* Probable Source *of some of the* Pebbles *of the* Triassic Pebble-Beds *of* South Devon *and of the* Midland Counties.

By Octavius Albert Shrubsole, Esq., F.G.S. (Read April 8th, 1903.)

Contents.

The strongly-marked character of the pebbles of the Bunter and the wide dispersal of so many of them in our old river-gravels have caused a considerable amount of speculation as to their origin. The subject, however, appears to me to be not yet exhausted; and this must be my apology for adding another to the long list of papers connected therewith.

I. Previous Investigations.

The first attempt to deal with the subject in a systematic way was in a paper on 'On the Pebble-Beds of Budleigh Salterton,' by W. Vicary & J. W. Salter, which appeared in the Journal of this Society for 1864.[1] In this important paper Salter came to the conclusion that the fossils found in the Budleigh-Salterton pebbles were not British types at all, but must be referred to the May Sandstone and the Grès Armoricain of Normandy. He did not, however, deal with all the material submitted to him, and admitted the existence of 'possibly Devonian' forms.

In 1867 the Rev. P. B. Brodie[2] drew attention to the lithological and palæontological resemblance between certain pebbles found in the Drift of Warwickshire and others in the Budleigh-Salterton Pebble-Bed.

In 1869[3] Thomas Davidson completed the work of J. W. Salter by showing that many of the Budleigh-Salterton pebbles did contain Devonian fossils (brachiopoda). He was inclined to look to some tract of land now occupied by the English Channel for the source of the pebbles.

In the same year appeared the Geological Survey Memoir on 'The Permian & Trias of the Midland Counties,' in which Prof. Hull suggested that the Bunter Conglomerate of the Midlands was an ancient 'Northern Drift' derived from the waste of the Old-Red-Sandstone Conglomerates in the Scottish area. He indicated the north or north-east as the probable direction from which they were brought, and the agency as marine. This view, however, he subsequently abandoned in favour of a more local derivation.

[1] Quart. Journ. Geol. Soc. vol. xx, p. 283.
[2] *Ibid.* vol. xxiii, p. 208.
[3] *Ibid.* vol. xxvi (1870) p. 70.

In 1876[1] Mr. Ussher contributed a paper to the Journal of this Society, 'On the Triassic Rocks of Somerset & Devon.' Referring to the Pebble-Bed, he indicated three distinct types of the formation which appeared to pass one into the other horizontally, the Budleigh-Salterton pebbles being succeeded northward by beds with small pebbles of quartz and grit, and finally by a conglomerate containing limestone-grit. This was followed in 1879 by a paper by the same author on 'The Triassic Rocks of Normandy & their Environments.'[2] He considered that the Keuper alone was represented in that area. Referring to the quartzites of May, he noticed a perfect lithological resemblance between them and some of the Budleigh-Salterton pebbles; but, on the hypothesis that the latter were a marine deposit, he saw no way of accounting for their transport from Normandy in Bunter times.

In 1880 appeared a paper in the Geological Magazine[3] by Prof. Bonney, 'On the Pebbles in the Bunter Beds of Staffordshire.' The various classes of pebbles were referred to and described; and, as a result of the study of the deposit as a whole, it was considered that the Conglomerate might represent the deltas of two large streams descending respectively from the north-west and the north-east.

The existence of quartzites in the vicinity of Loch Maree strongly resembling the light-coloured quartzites of the Bunter, also the marked resemblance between the Torridon Sandstone and the quartz-felspar grits of the Bunter, were adduced in support of the view that the pebbles of the Bunter came chiefly from the north. A second kind of quartzite was noticed in the Bunter pebbles, and this occasionally was found to contain fossils.

In the same year Thomas Davidson[4] described the Brachiopoda of the Grès Armoricain of Britanny (Lowest Llandeilo). It is characterized by *Lingula Lesueuri*, *L. Hawkei*, *L. Salteri*, and *Dinobolus Brimonti*,

'species that have not hitherto been discovered in any rock, *in situ*, in Great Britain.'

All these species occur in the Budleigh-Salterton pebbles. He was inclined to look for the parent rocks

'to France, or to an extension of Silurian and Devonian rocks that may have existed in the Channel and nearer to Devonshire.'

The whole subject was reviewed by Mr. Jukes-Browne in the eighth chapter of his book on 'The Building of the British Isles' 2nd ed. (1892). He supported Prof. Bonney's view that the pebbles were brought into the Bunter by fluviatile agency; and said that, if some of the Budleigh-Salterton pebbles were really identical with those of the Midland Bunter,

'their existence in the south would suggest a common source in the tract which separated the two areas of deposition.' [*Op. cit.* p. 193.]

He quoted the investigations of Dr. Sorby and J. A. Phillips on

[1] Quart. Journ. Geol. Soc. vol. xxxii, p. 367.
[2] *Ibid.* vol. xxxv, p. 245.
[3] Dec. 2, vol. vii, p. 404.
[4] Geol. Mag. 1880, p. 337.

the 'millet-seed' sandstones of the Lower Bunter, in support of the view that large desert-tracts, with their usual accompaniment of blowing sands, existed in the British region.

In 1881 the Rev. P. B. Brodie[1] again drew attention to the resemblances between the Midland and Devon pebble-beds. He gave a list of fossils found in quartzite-pebbles in the Drift; and was led to the conclusion that these had been derived from Keuper beds which may once have existed in the Midlands. These again derived their pebbles from the Bunter; and for their ultimate source he suggested a north-easterly extension of the Armorican massif, at no great distance from the Midland area.

In the same year Davidson, in his important monograph of the British Fossil Brachiopoda,[2] gave a complete list of all the brachiopoda of the Budleigh-Salterton Pebble-Bed. His list included 8 Ordovician species and 34 Devonian. He adopted the opinion that they were derived from some part of the 'Channel,' rather nearer the British than the French area. He rejected the view that the Ordovician rocks of Gorran Haven or other localities in Cornwall had furnished any of the pebbles.

In 1882 Mr. W. J. Harrison[3] expressed the opinion that the Midland pebbles were accumulated in a gulf or arm of the sea, and were derived from high land lying immediately to the east and now covered by Mesozoic deposits. He noted also the occurrence of quartzite-pebbles containing Devonian fossils similar to those found at Budleigh Salterton.

In 1883[4] Prof. Bonney, referring to the pebbles of Cannock Chase, noted the occurrence of a porphyritic quartz-felsite which was most like the felstone of the Southern Uplands and part of the Highlands of Scotland. He also found in one of the pebbles, *Lingula Rouaulti*, Salter (=*L. Hawkei*, Rouault), a fossil of the Grès Armoricain. In 1890 Prof. Bonney further remarked on the resemblance between the quartzites of the Loch-Maree district and the Torridon Sandstone, and certain pebbles in the Bunter of the Midlands.

In 1890 the late G. H. Morton[5] described the Lower Trias in the Liverpool district. He noted that the pebble-beds were 1000 feet thick, but that most of the pebbles were small. He was inclined to think that this detritus was brought by two great rivers, from the north-west and the north-east.

In 1892[6] Prof. Hull compared the pebble-beds of Budleigh Salterton with those of the Midlands. He remarked on the identity in character between the two deposits, and regarded the Budleigh-Salterton Pebble-Bed, with the overlying pebbly sandstone, as the equivalent of the Middle Bunter of the Midlands. The pebbles had

[1] Quart. Journ. Geol. Soc. vol. xxxvii, p. 430.
[2] 'Monogr. Brit. Foss. Brachiop.' vol. iv (1881) p. 317 (Palæont. Soc. vol. xxxv).
[3] Proc. Birmingham Phil. Soc. vol. iii, p. 177.
[4] Geol. Mag. 1883, p. 199.
[5] *Ibid.* 1890, p. 497.
[6] Quart. Journ. Geol. Soc. vol. xlviii, p. 60.

apparently been derived from the same unsubmerged land at the same period, rolled about, and finally laid to rest contemporaneously, though possibly in disconnected inland lakes or seas. He indicated the Palæozoic ridge lying between the two areas as a probable source, but observed that there was no doubt that some of the fossils of the Budleigh-Salterton Conglomerate had come from Normandy and Britanny.

In 1895 Prof. Bonney[1] described the pebbles of Budleigh Salterton, and compared them with those of the Midlands. He observed the general resemblance of the two deposits, with slight differences, drew attention to the occurrence of felstones and quartz-felspar grits in both localities, and suggested the possibility that the ancient mass of Archæan crystallines which once swept round from the Scoto-Scandinavian region to North-Western France may have been fringed in more than one district with rocks of Torridonian and Durnessian types.

In 1900 Prof. Bonney summed up his conclusions in a paper read before this Society.[2] He regarded the Midland Bunter pebbles as the work of a river or two rivers. He gave reasons for regarding it as highly improbable that these pebbles can have flowed from the south or south-west, or from any neighbouring district. The only direction practically left was, therefore, the north, although a certain portion of the material might be local. The Devon Pebble-Bed might be the delta of a third river—from a more or less westerly quarter, that is, from the old Armorican land, but chiefly draining an area which would include a part of Cornwall and of the English Channel.

In 1902 Mr. H. H. Thomas[3] submitted to this Society the result of an investigation of the fine material in the Budleigh-Salterton Pebble-Bed. This led him to conclude that the flow of the current which brought the pebbles with their sandy matrix was from south to north; and that there had been a tributary current from the west, but north of Budleigh Salterton.

From the foregoing general summary it will be seen that, although the earlier investigations were restricted in great part to the Pebble-Bed at Budleigh Salterton, and that subsequent observations had reference in the main to the Midland Bunter, it has not been possible to shut out considerations which involve the origin of the Pebble-Beds taken as a whole. This larger enquiry may be said perhaps only to have entered upon its initial stage; and as the Devon Pebble-Bed may possibly furnish us with a key to the position, I propose to consider the evidence regarding that particular deposit.

II. The Budleigh-Salterton Pebble-Bed.

In South Devon the Bunter Conglomerate may be observed in a magnificent cliff-section, showing not only the whole thickness of

[1] Geol. Mag. 1895, p. 75.
[2] Quart. Journ. Geol. Soc. vol. lvi, p. 287.
[3] *Ibid.* vol. lviii, p. 620.

the Pebble-Bed, but the entire series of red rocks above and below. The dip is easterly. The pebbles, as they rise from the beach at Budleigh Salterton, form a nearly perpendicular cliff, and finally crop out on the surface about a mile west of the town, where they form a belt of wild heather-clad country. I estimated the thickness of the bed at about 70 feet. Earlier estimates are somewhat higher, which may be accounted for by the wearing away of the cliff and the northerly thinning of the bed. It overlies and is succeeded by soft red sandstones, which at Straight Point, near Exmouth, pass into a harder sandstone with breccia.

There is no passage-bed between the pebbles and the sandstone. They come on suddenly, and appear to depart suddenly, although there is no apparent unconformity, at least at the base. The pebbles are thickly crowded in a matrix of hard purple or red sand.

The cliff is rather dangerous to approach, as it wears away rapidly; but the bed of pebbles may be seen in a chine made by a small watercourse, by which the cliff may be ascended. Here may be observed the promiscuous way in which the pebbles are arranged. They do not lie all in their angle of rest, but with their long axes in various directions. I mention this, as the contrary has been stated.[1] So simple a matter can easily be cleared up by further observations. The pebbles vary in size from half an inch to a foot in their longest dimension. They are not sorted as pebbles frequently are, by tidal or current-action; but all sizes are mingled together.

I took particular notice of the shape. Prof. Bonney[2] has described them as varying

'from subrotund to well-rounded, the larger specimens being sometimes almost subangular;'

and while remarking that the general resemblance to the Cannock-Chase Bunter pebbles is 'very marked,' he observes that the 'subrotund to subangular stones from 8 inches to a foot long' are rather more numerous at Budleigh Salterton. I am willing to accept this description. The fact is that the pebbles are variable in shape, and (the larger ones particularly) imperfectly formed; yet in many of them there is the tendency to be longer than broad and broader than thick. Some, however, are more or less what may be called 'sausage-shaped.' The shape is not unimportant, because it will help us to understand the mode of transport; and it does not support the view of those early observers who regarded this pebble-bed as a marine beach.

What marine action is may be seen in the modern beach at Budleigh Salterton. This is composed to a very large extent of pebbles which have fallen from the pebble-bed in the cliff. As soon as these come within reach of the waves, they are quickly reduced in size and flattened. The shore being steep, this action is very energetic. As each wave recedes, the stones can be heard slipping back

[1] H. J. Carter, in Davidson's 'Monogr. Brit. Foss. Brach.' vol. iv (1881) p. 318 (Palæont. Soc. vol. xxxv).
[2] Geol. Mag. 1895, pp. 76, 77.

over each other with a grinding noise. The result is to produce a new deposit altogether, in which the pebbles are usually of a totally different shape. They now become as a rule symmetrical, and lose all trace of angularity.

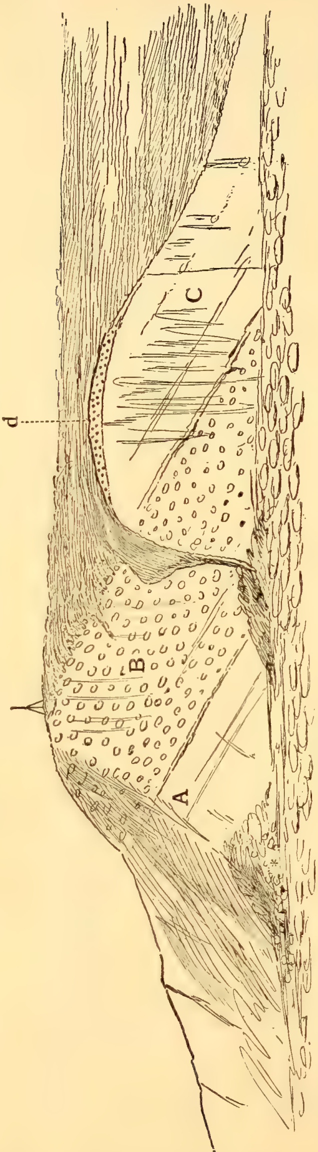

Fig. 1.—*View of West Cliff, Budleigh Salterton.*

A = Red marl, with grey seams. B = Pebble-Bed. d = Gravel (90 per cent. consisting of rearranged pebbles).
C = Red sandstone, with clayey seam: pebbly in the upper part. * = Fallen blocks, with septarian nodules.

The Pebble-Bed, therefore, must be examined in inland sections. There are extensive gravel-pits between Budleigh Salterton and Exmouth, in which the pebbles are worked for road-metal. In other parts of England where flint and other hard materials are abundant, the Triassic pebbles are usually regarded as an undesirable element, from the difficulty of breaking them up. Here, however, they form the sole material readily available for mending the roads; and the men who are employed in breaking up the stones are of a fine muscular type, bringing to the work not only strength, but skill, for they have acquired the knack of knowing the best way of attacking a stone with success, so as not to waste their blows. They informed me, however, that the larger pebbles cannot be broken up without a sledge-hammer.

It may be well also to state that much of the ground in this district is covered by Drift which contains a large proportion (90 per cent.) of the pebbles.

With regard to the rock-material of which the pebbles are composed, I cannot add anything to Prof. Bonney's description.[1] Its general character is, of course, the preponderance of quartzites of varying texture and colour, often of some shade of

[1] Geol. Mag. 1895, p. 75.

red or purple, and the entire, or almost entire, absence of many important rock-groups. As in the Midlands, there is a small proportion of tourmaline-grit and quartz-felspar grit.

Prof. Bonney also states that both deposits

'contain some felstones, with more basic rocks of compact structure and purplish colour; also granitoid rocks in a very rotten condition.'[1]

It would indeed be difficult to describe the deposit in general terms which would not equally apply to the Bunter Conglomerate of the Midlands.[2]

Judging only from lithological evidence, the bulk of the pebbles must have come from a definite region of a comparatively simple geological character. The palæontological evidence also, as originally stated by Salter, confirms this, and, by showing that the Ordovician fossils, at least, are of Norman types, points definitely to a southern source. This is in accordance with the evidence of the Pebble-Bed itself, which appears to have been thicker in the part which has been removed by the sea, and, as Mr. Ussher has shown,[3] seems to die out in a northerly direction, so that at Burlescombe only small quartz- and grit-pebbles were found.

The large number of Devonian brachiopoda occurring in the Budleigh-Salterton pebbles may possibly have induced Davidson to favour on the whole the 'mid-Channel' hypothesis, although he admits that the pebbles, or many of them, may have come from France. But, apart from the question whether the number of Devonian fossils affords any index to the proportion which the Devonian pebbles bear to the whole, the fact must be borne in mind that, with the exception of *Spirifera Verneuilii* and *Sp. speciosa*, the whole of the list given by Davidson consists of species which do not occur *in situ* anywhere in Britain. Since they are non-British types, it is surely not necessary to look as near to the British area as possible for their original source.

And we have another fact to guide us. The pebbles at Budleigh Salterton which contain Devonian fossils are associated with others which contain Ordovician fossils, and these are all, or almost all, identical with Norman forms. Now, the old Ordovician land of Normandy must at one time have had other ancient rocks superimposed upon it. There are still in the Calvados fragments of Silurian and Carboniferous brought in by faults, and the Devonian is represented in parts of Normandy and Britanny. What supposition, then, is more natural than that the Devonian was once represented either in the Calvados district, or in some region in the same drainage-area as that which has supplied the Ordovician element of the Budleigh-Salterton pebbles?

The claim, therefore, that Normandy (or some land anciently connected therewith) was the source from which the pebbles were originally derived, is so strong that it demands a special examination.

But, in fact, no other source has been seriously advocated; for

[1] Geol. Mag. 1895, p. 76.

[2] See T. G. Bonney, *ibid.* 1880, p. 404.

[3] Quart. Journ. Geol. Soc. vol. xxxii (1876) p. 367.

the supposed 'mid-Channel' source falls into this category, if we admit that the English Channel had then no existence.

Some part or extension of Cornwall has also been mentioned as a possible source. A few Ordovician fossils of southern type have certainly been found here, but, I believe, no purple quartzites. And Cornwall is not exactly the direction in which we should naturally look, for it does not seem to supply the necessary physical conditions; although, as Prof. Bonney has shown, it was part of the ancient Armorican massif.[1] But it was proved by Davidson that the fossil-evidence is insufficient, for only two Grès-de-May species of Budleigh Salterton are found at Gorran Haven, while the Grès Armoricain is unrepresented.[2]

We have to look, then, for a region—

(*a*) In the direction of the thickening of the Pebble-Bed;

(*b*) of sufficient extent and height to have furnished the mass of the pebbles;

(*c*) which contained in Triassic times the same hard rocks as those that are found in the Pebble-Bed, and no others.

III. The Grès de May of Normandy, and its Associated Rocks.

In the Armorican peninsula we have an example of an old land-surface which has been so worn by long exposure to denuding agencies, that over the greater part of Britanny nothing but the granitic core with gneisses, etc. is left. The original height of the massif can only be guessed at; but Prof. Bonney remarks that its breadth, including the connected area, must have exceeded that of the Alps.[3] In parts of Normandy, however, this process of wasting was arrested by the deposition of Mesozoic sediments; and these again have been denuded, so that the old Palæozoic rocks are usually but thinly covered, or are once more exposed at the surface, while the rivers have everywhere cut into the older rocks. Even in Normandy a large part of the surface is occupied by the Phyllades de St. Lô, which are considered to be of Archæan age, and form the characteristic soil of the Bocage.

The Palæozoic rocks are represented in descending order principally by the

Grès de May.
Schistes Ardoisiers (Schistes d'Angers).
Grès Armoricain.
Purple 'Schists' } = Grès à Bilobites.
Purple Conglomerate }

The Grès de May is further subdivided as under:—

A. Grès du sommet (*Conularia pyramidula*, *Homalonotus Deslongchampsi*, *Modiolopsis Morierei*, *M. prima*).

B. Niveau schisteux à *Trinucleus Bureani*, with *Calymene Tristani*, etc.

C. Grès à *Homalonotus* (*Homalonotus Vicaryi*, *H. serratus*, *H. Brongniarti*, with *Plæsiacomia brevicaudata*, *Dalmanites incerta*).

D. Grès minces de la base, à *Calymene Tristani*. Often ferruginous.

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[1] Quart. Journ. Geol. Soc. vol. xliii (1887) p. 320.

[2] 'Monogr. Brit. Foss. Brach.' vol. iv (1881) p. 330 (Palæont. Soc. vol. xxxv).

[3] Quart. Journ. Geol. Soc. vol. xliii (1887) p. 320.

The Grès de May is now only represented by a few small isolated patches; but it is evident that it was once a large and thick formation. Small as the exposures are, however, they are of considerable commercial importance. At May, where the rock is quarried for paving-stones, it has a thickness of 985 feet, but the outcrop is less than 3 miles in length, with a width of half-a-mile. The beds dip at an angle of about 45°, and consist mainly of a tough massive quartzite of medium grain and with conchoidal fracture. This alternates, however, with dark fissile seams and with sandstones which are generally pink. The characteristic hard quartzite is of various colours: it may be nearly white to various shades of red, and sometimes it is grey or brown. The red coloration occurs very irregularly, and is due to infiltration. Prof. Bonney has detected a deposit of ferrite. This infiltration can frequently be seen to have penetrated along joints and bedding-planes, and near the base of the Grès de May there is a ferruginous band. In the Grès Armoricain there is a deposit of red hæmatite, which is still worked in the vicinity of May and at other places; and I observed, in passing through the village of Feuguerolles during a shower of rain, that the flood-water was stained red.

The Grès de May at this place is on the banks of the River Orne, and has been exposed by valley-erosion, as is the case at Gouvix, in the valley of the Laize. At both these places human agency is rapidly accelerating the work of Nature.

In other localities the Grès de May, although of small superficial extent, constitutes the dominant ground of the district. It forms the summit of a ridge near the village of Jurques, at an altitude of 1185 feet. It is here a white quartzite, fossiliferous, and usually free from the red staining. It occurs again at Montpincent, the highest point in the Calvados, where it is also of a whitish colour. There are only shallow workings in it for the purpose of road-making, but its comparative hardness doubtless accounts for its elevated position.

There are other detached exposures of the Grès de May near Falaise, and at various other localities in the Calvados. It is evident that we have in these the last surviving remnants of a formerly extensive and important deposit, which was originally the bed of the Ordovician sea. And, when we have regard to the extent and the original thickness of the deposit, we can see that it was capable of furnishing abundance of material, not only for the Ordovician pebbles of the Budleigh-Salterton Pebble-Bed, but also for a great deal more. Davidson[1] pointed out that there were many Lower Devonian fossils in this pebble-bed. This fact renders it extremely probable that the Devonian was once represented in those parts of Normandy where now only the Ordovician is found.

The denudation has been less severe in the case of the lower members of the Ordovician Series, which still occupy a considerable area. As a whole, the Grès Armoricain, with its associated rocks,

[1] 'Monogr. Brit. Foss. Brach.' vol. iv (1881) p. 323 (Palæont. Soc. vol. xxxv).

is not so hard as the Grès de May, and does not seem to have furnished so much of the material of the Budleigh-Salterton pebbles as the latter. Yet it is sometimes difficult to distinguish particular specimens of the two sets of rocks.

The Grès Armoricain at its base passes into a grès feldspathique, which to the eye bears a strong resemblance to the quartz-felspar grit both of Budleigh Salterton and the Midlands. Prof. Bonney's remarks on one specimen from the May district will be found farther on (p. 321).

The fact, first pointed out by J. W. Salter,[1] that the Ordovician fauna of the Grès de May, belonging to the southern or Continental type, is that which is represented in the Budleigh-Salterton pebbles, has never, I believe, been seriously questioned. M. G. de Tromelin, in his monograph on the Grès de May of the Calvados, shows that out of 62 species described, 36 only are common to that locality and to all other parts of the West of France, while 21 of the species are found at Budleigh Salterton. This is a very remarkable fact, when the conditions at Budleigh Salterton are taken into account; and it shows that the fauna which is characteristic of the Calvados district is largely represented at Budleigh Salterton. Salter was unable to detect any difference in the fossils which are common to the two localities. The bearing of this point is important, because, while Davidson admitted the possibility of the pebbles having come from France, he confessed a preference for a locality as near the present British shore as possible, and thus there has been a tendency to derive the Budleigh-Salterton pebbles from the south-west, whereas the palæontological evidence alone indicates rather the south-east.

It may be convenient to reproduce from the monograph of M. G. de Tromelin on the Grès de May[2] the list given by him of the species which are common to the Grès de May and the Budleigh-Salterton Pebble-Bed. This, of course, does not include the Armorican Grit, but it will serve to indicate the probable source from which many of the pebbles have been derived:—

Dalmanites incerta = *Phacops incertus*, Salter.
Homalonotus brevicaudatus (Desl.).
H. Brongniarti (Desl.).
H. Deslongchampsi, Trom.
H. Vicaryi, Salt.
Ribeiria conformis, Salt.
R. magnifica, Salt.
Tigillites Dufresnoyi, Rou. (*Trachyderma serrata*, Salt.).
Conularia pyramidata, Hœningh.
Arca Naranjoana, Vern. Barr.
Ctenodonta bussacensis (Sh.).
Ct. erratica, Trom.
Clidophorus amygdalus, Salt.
Modiolopsis Heraulti, Trom.
M. lirata, Salt.
M. prima (d'Orb.).
Lingula Morierei, Trom.
Orthis budleighensis, Dav.
O. Berthoisi (var. *erratica* ?, Dav.).
O. exornata, Sharpe.
Vexillum Halli (?) Rou.

[1] Quart. Journ. Geol. Soc. vol. xx (1864) p. 287.

[2] 'Étude de la Faune du Grès Silurien de May, &c.' Bull. Soc. Linn. Norm. ser. 3, vol. i (1877) p. 74.

Almost all these species are stated to occur at the quarries of May. This fact is of some interest, for the Grès de May itself, which is not found farther west than the department of the Manche, appears to be subject to local variation in its palæontological facies. There are also allied grits, having a somewhat different fauna, in the department of Ille-et Vilaine, etc.; but if any one locality be taken, the greater number of correspondences will be found in the Ordovician of May.

The lithological evidence is equally remarkable. It was noticed by J. W. Salter,[1] Mr. Ussher,[2] and A. Wyatt Edgell.[3]

On the occasion of two visits to the district, I was much impressed by the apparent lithological identity between the Grès de May and a very large proportion of the Bunter pebbles. The resemblance extends to peculiar and strongly-marked features, such as the irregular way in which the quartzite is frequently stained with red patches or blotches, and it is worthy of note that these resemblances are especially conspicuous at the quarries of May. At Jurques and Montpincent the staining is usually absent. At May I noticed the close similarity between the softer parts of the May sandstone and certain soft reddish pebbles in the Drift which had puzzled me as to their origin.

I found a section of the Grès feldspathique by a roadside near the village of May, and was at once struck by its strong resemblance to the quartz-felspar grit of the Bunter and of our river-gravels. The rock itself in this small section was found to be variable, both in the size and proportion of the felspar-grains, which is the case also with the Bunter pebbles; so that, in comparing specimens from one locality with another, only a general resemblance in type would be expected.

I am aware that the argument from lithological similarity should not be pushed too far; but, in order that we may know all that can be known regarding these rocks, I submitted certain types to Prof. Bonney, and he has kindly sent me the results of his examination of them. On No. 1 (a specimen of the May sandstone, or quartzite, from the quarry at Feuguerolles) Prof. Bonney remarks:—

'1. (May) Hand-specimen.—Very like the liver-coloured quartzite found in pebbles both in the Midlands and at Budleigh Salterton.

'Microscopic characters.—Grains fairly rounded, distinctly outlined by a deposit of ferrite. There may possibly be one or two minute grains of tourmaline. In the Midland specimens the grains are much more angular, and much less distinctly outlined, but with a general appearance as if they themselves were coloured. The latter also contain granules of zircon, rutile or sphene (perhaps both), and probably tourmaline. But as the localities are far away, the differences may not be worth much.

'2. Grès feldspathique (near May). Hand-specimen.—Very like Torridon Sandstone and the quartz-felspar grit of the Bunter Pebble-bed,

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[1] Quart. Journ. Geol. Soc. vol. xx (1864) p. 287.
[2] *Ibid.* vol. xxxv (1879) p. 245.
[3] *Ibid.* vol. xxx (1874) p. 45.

but paler in colour, and more like the Grès feldspathique of the Cherbourg district. The latter, which is less well preserved, is considered to be about the age of the *Lingula*-Flags (Tremadoc not distinguished), the overlying quartzite, which is very like the Stiper-Stones quartzite, being referred to the Arenig Series.

'Microscopic characters.—Some of the grains are fairly rounded, and some are composite. There is microcline among the felspar. Very like some of the Torridon Sandstone of Scotland; also resembling the Bunter quartz-felspar pebbles, which, however, are generally rather less well preserved.

'3. [A bright red pebble taken from the beach at Budleigh Salterton. Although flattened by marine action, it was obviously derived from the pebble-bed.]

'Hand-specimen.—A typical Salterton pebble, rather paler than the liver-coloured, and I think a little different; nearer to the ordinary white type.

'Microscopic characters.—A fine-grained more grit-like quartzite than the usual Bunter type. Certainly contains tourmaline (brown). I do not think the microscopic distinction very strongly marked.'

I may remark that I selected the last-named specimen, because of its being of a particularly bright-red colour. The resemblance of hand-specimens, as will have been seen by the examples submitted, is very close and striking.

There is another very characteristic pebble found at Budleigh Salterton as well as in the Midlands, namely, a veined black grit, formerly known as lydianstone, and now generally known as a tourmaline-grit. The general impression is that the rock comes from Cornwall, as it appears to be unknown in the northern districts. I was not so fortunate as to find any of it *in situ* in Normandy, but I find a reference in MM. G. de Tromelin & P. Lebesconte's work [1] to a black quartzite veined with white ('quartz-lydien') occurring in the department of Maine-et-Loire, and containing graptolites of Llandeilo age.

Putting all these facts together, we find that there are, or probably have been, rocks in Normandy which will account for a very large number of the Budleigh-Salterton pebbles. On the other hand, rocks which are not represented in the pebbles to any appreciable extent, either do not occur in Normandy, or if they do occur (as in the case of the Phyllades de St. Lô) they were probably covered by other deposits, and were not undergoing erosion in Triassic times. The connection is too close to be accidental; therefore it appears a reasonable conclusion that the mass of the Budleigh-Salterton pebbles has been derived from some part of the ancient Armorican highlands. If they were brought by a single large river, that river doubtless drained a considerable area, including probably the Calvados district of Normandy, part of the Channel area, and possibly part of Britanny, and the general direction of its flow must have been northward.

[1] G. de Tromelin & P. Lebesconte, 'Essai d'un Catalogue raisonné des Fossiles siluriens des Départements de Maine-et-Loire, de la Loire-inférieure & du Morbihan, &c.' C. R. Assoc. franç. Avancem. Sci. (Nantes) 1875.

IV. The Bunter Conglomerate of the Midlands.

This very distinct deposit has long attracted attention, but without evoking much serious or systematic study until recent years. The Geological Survey Memoir in 1869, however, devoted some pages to it. In 1880,[1] and in numerous subsequent papers, Prof. Bonney dealt especially with the lithology of the pebbles and their physical history, yet very little has been done beyond the work accomplished by Prof. Bonney himself in the way of determining species. This is somewhat singular, when it is considered that fossil-evidence is usually regarded as the most trustworthy of all geological data, and that a comparatively rich fauna in the Budleigh-Salterton pebbles was known to us nearly forty years ago.

The Midland Bunter, where it is most typically represented, has certainly a strong general likeness to that of Devon. I was impressed by that resemblance when visiting the quarries at Exmouth and Repton respectively. I did not make a minute analysis in the former case; but an examination of 100 large pebbles from the pit near the village of Repton gave the following result:—

Pebbles from Repton Quarry.

		Per cent.
Crushed or brecciated quartz-rock		1
Quartz		4
Quartzite, purple and brown	39	73
Quartzite of various colours	34	
Purple and other grit		7
Sandstone		6
Compact rock, not precisely determined		8
Quartz-felspar grit		1
		100

Although probably the next hundred of pebbles would have given a slightly different analysis, the above may suffice to give a general idea of the composition of the pebbles in this part of the Midlands; and it probably holds good in a general way for other districts. It amounts to this, that 80 per cent. of the largest stones consist of the quartzites and grits, many of which are of the characteristic purple colour; and it is these which must demand our principal attention when instituting a comparison.

An examination of the smaller stones would have given somewhat different results. For instance, in the above there is very little vein-quartz and no tourmaline-grit, the latter of which certainly occurs. And Prof. Bonney informs me that felstones are not rare all over Cannock Chase, and other igneous rocks are found, although they are scarce and (if granitoid) rotten.

An idea of the material of the Bunter was also obtained from

[1] Geol. Mag. dec. 2, vol. vii, p. 404.

an examination of surface-drift, which consists practically of rearranged Bunter pebbles, at two points on the Lickey:—

	Near Station.	*Near Church.*
Quartz-conglomerate or breccia	...	2
Vein-quartz	11	18
Quartzite, purple and brown	50	51
Quartzite of various colours	21	11
Quartzite, green	3	2
Purple and other grit	6	8
Other rocks	9	4
Subangular material (Drift)	...	4
	100	100

The Bunter Conglomerate in England can nowhere be said to be a heterogeneous deposit. Two cartloads of pebbles taken from different sections, or even from the same section, would doubtless be found to differ slightly; but the difference is within fixed limits, and the analysis tabulated above may be taken to represent the type of large material in a general way, whether in Derbyshire, Staffordshire, Worcestershire, or Devon. This general resemblance was noted by Mr. Ussher [1] as being 'abnormally striking.' It is significant, both in regard to what is included and what is absent or present only in moderate quantity. The proportion of hard sedimentary rocks more or less metamorphosed is very high, and there is only an extremely moderate percentage of vein-quartz. This agrees very well with the Grès de May and the Grès Armoricain of Normandy, in which quartz-veins are not common. There are, moreover, always a few comparatively-soft reddish sandstones; and these agree in appearance with the softer beds in the Grès de May.

The pebbles, on the whole, are rounded, yet not always so completely rounded as to have lost all trace of angularity. Even in the Thames quartzite-gravel, where it must have had a further journey of 60 or 70 miles, I have picked up a subangular fragment of red quartzite. In the north-west, as is well known, the pebbles become smaller and more rounded, and are more largely composed of vein-quartz.

For the purpose of comparison with the Normandy rocks, I submitted to Prof. Bonney certain specimens of Bunter pebbles—two from an undisturbed section at Repton, and three from the valley-gravel at Reading. The last-mentioned were included, because there is strong evidence which justifies us in believing that such pebbles of the characteristic liver-coloured type have been derived from the waste of the Bunter Conglomerate; and it was desirable to confirm this, as far as it is possible to do so, by microscopic examination.

Prof. Bonney reports on these specimens as follows:—

'No. 4. Repton.

'Hand-specimen.—The usual "Torridonian" of the Midland pebbles.

'Microscopic characters.—As usual, but little better preserved than

[1] Quart. Journ. Geol. Soc. vol. xxxiv (1878) p. 464.

my Staffordshire specimens. Might have been collected in the North-West of Scotland.

'No. 5. Repton.

'Hand-specimen.—The "liver-coloured" quartzite of the pebble-bed.

'Microscopic characters.—Grains rather more rounded than in my specimen, and the colouring is more on the outside (in fact, nearer to the May specimen). Inclusions: zircon, rutile, and possibly tourmaline.

'No. 6. Reading (Drift).

'Hand-specimen.—Just like a "liver-coloured" quartzite.

'Microscopic characters.—Finer-grained than my Midland specimens, and in that respect more like No. 3 from Salterton (p. 322), but it encloses a few larger grains. Colouring about the same as No. 5. Inclusions: zircon (not rare), tourmaline, and rutile or possibly staurolite.

'No. 7. Reading (Drift).

'Hand-specimen.—May be the liver-coloured variety, but has not quite the "shimmer" of the most typical.

'Microscopic characters.—Irregular in size of grain. Very "dirty." I think that there is zircon, also rutile, and a brown mineral which I imagine can hardly be the latter; it may be staurolite, but I am not sure.

'No. 8. Reading (Drift).

'Hand-specimen.—Apparently a liver-coloured quartzite.

'Microscopic characters.—This is perhaps a little more stained and slightly more irregular in size of grain than the other liver-coloured specimen, and so holds out a hand to the last-named. Still, there is a difference not easily expressed in words.'

Prof. Bonney's remarks are of great value, for while they show that pebbles, extremely similar in appearance and coming from the same deposit, present slight internal differences, they bring out only the more clearly the strong family likeness subsisting between certain specimens in the northern and southern Bunter, and some of the undisturbed rocks of Normandy.

Into this family group must also be received the Torridon Sandstone of the North-West of Scotland. This fact may be freely admitted, and will justify such inferences as may be fairly drawn from it; but, in pursuing an investigation, the evidence must be taken as a whole.

V. The Palæontological Evidence.

When it is remembered how considerable a fauna has been obtained from such unpromising material as the Budleigh-Salterton pebbles, it is a matter for some surprise that fewer fossils have been obtained from the much larger mass of the northern Bunter pebbles, which appear to be composed of similar types of rock-material. The difference may be due to the fact that the one has been more systematically explored than the other. I was myself unable, in a fortnight's search, to find more than one or two fossiliferous pebbles at Budleigh Salterton; but it is probable that these are not unknown to the men who break up the pebbles for road-material.

It cannot be said that the Bunter pebbles are unfossiliferous.

The Museum of Practical Geology in Jermyn Street contains the following species found in pebbles in the Bunter by Prof. Bonney and Mr. S. G. Perceval:—

Orthis budleighensis	Cannock Chase.
Branching coral	Two small fragments. Same district.
Trachyderma serrata (?)......	Near Lichfield.
Cornulites serpularius.........	In one flattish pebble of dark-orange sandstone. Cannock Chase.
Strophomena sp.	
Favosites sp......................	
Atrypa reticularis	
Petraia bina ? (cast)	Tamworth.

In addition to these, Prof. Bonney[1] has reported the occurrence of

Rhynchonella sp.	*Lingula Hawkei* (Rouault)
Orthis sp.	= *L. Rouaulti* (Salter).
Glyptocrinus.	

This list is a somewhat disappointing one. I think it likely that other species may have been found, which have unfortunately not come to my knowledge. The above list, however, contains three southern forms, *Orthis budleighensis*, *Lingula Hawkei*, and *Trachyderma serrata (?)*, which have to be accounted for; but the number of specimens is too small for the purpose of comparison.

Fortunately, we are not dependent upon specimens obtained *in situ* from the Bunter. It is well known that vast quantities of pebbles from the Bunter occur in the various gravel-deposits which are found not only near the outcrop of the Conglomerate, but spread far and wide along the upper slopes of our river-valleys. They are very plentiful, for instance, in the Thames Valley, and may be traced up the valley of the Evenlode, almost without a break, up to the district around the Lickey, where the Conglomerate is marked on the map, although it is obscured by its own Drift.

Owing to their being spread over a larger area, and to the great attention which has been paid to the problems connected with the Drift, these pebbles have been studied by a number of observers, and a not inconsiderable list of fossils has been obtained. The Rev. P. B. Brodie gave a good deal of attention to the Drift around Warwick, and the results which he communicated to this Society are most important and interesting.[2] He pointed out the close relationship of the fauna of these pebbles with that of Budleigh Salterton.

There is naturally an element of uncertainty as to the origin of derived pebbles or fragments. That element, however, is assuredly very small when they contain fossils, and smaller still when the fossils as a whole present strongly-marked or special characters.[3] The slight element of uncertainty which is left is not sufficient to

[1] See Geol. Mag. 1880, p. 406.

[2] Quart. Journ. Geol. Soc. vol. xxxvii (1881) p. 430.

[3] A pebble crowded with *Orthis budleighensis* from Sparkbrook, Birmingham, may be compared with a similar pebble from Budleigh Salterton. Both are in the Museum of Practical Geology, Jermyn Street.

affect general conclusions. Indeed, in practice, it is not difficult to recognize a typical Bunter pebble wherever it may be found. There is consequently little fear of serious error in admitting the evidence derived from fossiliferous pebbles found in the Drift, if there be no special reason for suspecting that they were not derived from the Bunter.

The following table is compiled from the published lists of Salter, Davidson, G. de Tromelin, Brodie, and others. Most of the specimens will be found in the Museum of Practical Geology, Jermyn Street:—

	Drift.	Budleigh Salterton.	Normandy.
Homalonotus Brongniarti	*	*	*
H. Vicaryi	*	*	*
Calymene Tristani	*	*	*
Orthis budleighensis	*	*	*
O. Berthoisi, var. *erratica*	*	*	*
O. Valpyana	*	*	*
Lingula Lesueuri	*	*	*
L. Hawkei	*	*	*
Spirifera Verneuilii	*	*	*
Stricklandinia lirata	*	...	...
Rhynchonella sp.	*	...	...
Arca Naranjoana	*	*	*
Clidophorus amygdalus	*	*	*
Modiolopsis lirata	*	*	*
Trachyderma serrata	*	*	*
Palæarca secunda	*	*	*
Petraia bina	*	...	...
Lyrodesma sp.	*	...	...
Glyptocrinus sp.	*	...	...
Orthoceras sp.	*	...	...

I have omitted from the foregoing list some doubtful forms, and it has no pretence to being absolutely complete. Other species may have been found, or will, I hope, come to light. But the work is slow, life is short; the pebbles are proverbially hard and tough; and the fossils, when found, are often difficult to determine. Nevertheless, the list tells its own tale clearly enough. All the most characteristic fossils of the Budleigh-Salterton pebbles are found in the gravels which have been obviously derived in part from the Bunter Conglomerate of the Midlands. Whence did the Bunter get these pebbles? Anyone has merely to look at a group of characteristic Caradoc fossils from Wales or Shropshire, or the Scottish area, to see that our fossiliferous pebbles of that age could not have come from either of those directions.

The hypothesis which presents the least difficulty appears to be that which regards the two pebbly deposits, north and south, as having had approximately a common origin.

There is no doubt, at present, a certain amount of discontinuity between the two areas; but it is possible to exaggerate that. The

Trias, as a whole, has a general north-to-south range. With regard to the Bunter Pebble-Beds, some old lines of connection may have been rubbed out; but we may reasonably infer some relationship when we find so many features in common. To take, for illustration, the case of the trilobites. Four species, all Norman types, have been found at Budleigh Salterton; three of these have already been found in the Midland pebbles, and no others.

Again, *Orthis budleighensis* is the commonest fossil in the Ordovician pebbles of Budleigh Salterton; it fills of itself whole beds at May, Jurques, Campandré, and Mont Robert.[1] It has been found in derived Bunter pebbles in the Pleistocene gravels by Mr. S. G. Perceval, at Sparkbrook, near Moseley; by Mr. W. J. Harrison, at Countesthorpe, near Leicester; by the late Mr. Vaughan Jennings, near Nottingham; by the late Rev. P. B. Brodie, near Warwick; and by Prof. Bonney, near Rugby. The present writer, moreover, has found it in the neighbourhood of the Lickey and in the gravel of the Thames Valley.

Again, the occurrence of so distinct a fossil as *Lingula Lesueuri* in all three districts is very significant.

Even if there should prove to be an uncertain or undetermined element in the Midland pebbles, whether found in the Bunter itself or derived, the correspondences which have been shown to exist must be accounted for.

There is, in fact, a distinct element in our older river-gravels, which does not come from the Bunter, and yet is not strictly local; but, beyond noting the fact, we have nothing to do with this at present.

VI. General Conclusions.

The result of my own observations has been, in the first place, to confirm Salter's opinion that the Budleigh-Salterton pebbles came chiefly from Normandy, or some land connected therewith. The subsequent determining of a considerable number of Devonian brachiopoda from the same pebble-bed, almost all of them being non-British types, appears to be of significance only in so far as it suggests that the Devonian and the Ordovician rocks cannot have been very far apart.

The Ordovician fauna is found to vary locally. In particular, the types are different north and south of the barrier indicated by Barrande. The fauna of the Calvados district is the most nearly related to that of the Budleigh-Salterton pebbles. We have seen that that district was probably undergoing erosion at the epoch of the Bunter Conglomerate. Indeed, the same thing may be said of the whole Armorican massif, which probably extended across what is now the Channel into part of the British area. This massif may have been mountainous at that time or not,—it is said by Prof. Bonney to have been broader than, if not

[1] G. de Tromelin, Bull. Soc. Linn. Norm. ser. 3, vol. i (1877) p. 65.

as high as the Alps [1]; anyhow, it must have been drained by some large river or rivers, and we know that a vast amount of sediment has been removed. Whither has that sediment gone? There are no local deposits that adequately account for it. There are Triassic rocks in Normandy, but they are of Keuper age. There are also pebbly sands which occur as a fringe around the old rocks, and are considered to be in part of Triassic age; but their extent is insignificant.

Now, why should not the drainage of that Armorican plateau have been in part at least northward? Many considerations render this probable. The Budleigh-Salterton Pebble-Bed, perhaps, may be thought to prove it; but if it prove that, it can suggest much more. And, therefore, I conclude that, whether the Budleigh-Salterton pebbles are exactly contemporaneous with the Bunter pebbles of the Midlands or not, the latter to a large extent represent the waste of the old Armorican plateau or the land connected therewith. (See map, fig. 2, p. 330.)

And this brings me to the question of the particular agency by which the pebbles were dispersed. I do not propose to discuss that question at length, as it has been so fully dealt with by Prof. Bonney in his various papers, which have, as it seems to me, made the old view which regarded these pebbles as a marine shingle-bank or beach-deposit practically untenable.

Let us, then, see how the theory of the fluviatile origin of the Bunter pebbles fits in with our facts. The facts, however, would remain in any case.

It is not pretended that we have any distinct evidence that the arenaceous beds of the Bunter have been derived from the waste of the Armorican land; but it is a possibility which it would be well to have in view, and there are some considerations which suggest it. When, however, we come to the pebbles suddenly intercalated in the sandstone, we may well ask by what agency they were brought, and under what conditions.

The Keuper is usually considered to have been a lake-basin; and it is difficult to conceive of the Bunter otherwise than as representing an initial stage in the same movement of depression—a lake-district fed at least by one great river from the south; but having too small a rainfall to enable it to take up much local material.

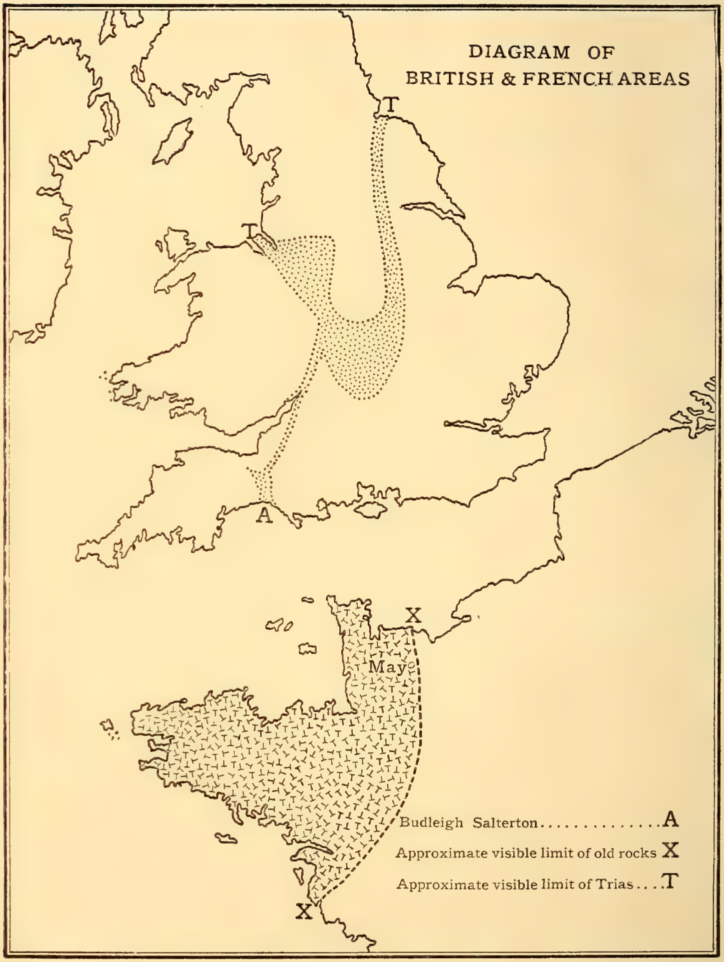
To account for the sudden appearance of the pebbles, we must of course find a sufficient cause. Some strong force must have moved them, so that they finally came to rest where only finer sediment had previously found its way, whatever may have been the direction from which the lower sandy beds came. It is useless to speculate on the precise cause of this change. It may have been a reversal of drainage, or a change of atmospheric conditions. Whatever it was, it must, if we accept the fluviatile hypothesis, have been very energetic.

While I suggest that the Devon pebbles may have been deposited

[1] Quart. Journ. Geol. Soc. vol. xliii (1887) p. 320.

by the same agency, and possibly at the same time, I do not contend that they were necessarily deposited by the same great river. There may have been more than one river coming in a direction generally from the south; but this is a speculation upon which it is needless to enter. Indeed, the facts which I have

Fig. 2.



submitted must be taken into account, whatever may have been the means of transport of the pebbles.

It might be urged, as an objection to the flow of the pebbly material from the south, that the Bunter as a whole thins out in a south-easterly direction. This is met, so far as the pebbles are

concerned, by the fact that in the same direction they become larger and more angular; and if we take, as a working hypothesis, the deposit of the Bunter in a lake-basin or area of depression, the conditions prevailing in the north-western area are easily explained.

The late G. H. Morton showed that the Bunter in the Liverpool district has a total thickness of 1950 feet, but of this 400 feet is a sandstone in which quartz-pebbles are dispersed, and 600 feet is a true pebble-bed. In this, however, the pebbles are principally white vein-quartz, quartzite, and a few other rocks. Very few are 6 inches in diameter, and they are perfectly smooth and 'must have come from a great distance.'[1] That is exactly what would happen in the deepest part of a depression such as has been indicated, if it were the farthest from the source of supply of materials. Finer material would tend to accumulate there; the pebbles would be smaller and more rounded, and by selective action those composed of quartz would predominate, on account not only of the hardness of the rock, but also its tendency to wear to a more rounded form, and so either to survive longer, or to travel farther than rocks of a less compact and amorphous structure.

The same conditions are observed, to a considerable extent, in South Devon. At Burlescombe the pebble-bed passes into or is succeeded by a deposit of small quartz-pebbles with grit-pebbles, and the pebbles are on the whole smaller north than south of Tallaton.[2]

Whatever may have been the exact physical conditions, all this is quite consistent with a general south-to-north direction of the current which brought the greater part of the materials.

I have not attempted a discussion of all the problems connected with the Lower Trias. My object has been rather to present certain facts which, if correctly interpreted, may possibly help us to understand other facts. But there is much yet to learn, and my purpose will be served if the present paper should lead to further investigations on the subject.

I must acknowledge my great indebtedness to Prof. Bonney for examining so fully the rock-specimens submitted to him, and for permitting me to make use of his observations thereon. I am all the more grateful to him for his help, because I know that he strongly dissents from some of my conclusions.

Discussion.

The Chairman (Mr. Teall) drew attention to the similarity of liver-coloured quartzites and to their occurrence in conglomerates of many ages. They were found in the Torridonian Sandstone of the North-West of Scotland, which clearly could not have been

[1] G. H. Morton, 'Notes on the Bunter & Keuper Formations in the Country around Liverpool,' Geol. Mag. 1890, p. 500.

[2] W. A. E. Ussher, Quart. Journ. Geol. Soc. vol. xxxii (1876) p. 367.

derived from the Ordovician. The frequency of their occurrence in conglomerates illustrated the law of the 'survival of the fittest.'

Dr. J. W. EVANS doubted whether the source of the majority of the pebbles could be nearly as distant as Normandy. He had an opportunity of examining those of the River Beni, at the point where it reaches the low country after traversing several ranges of the outer Eastern Andes. Almost all the pebbles were such as might have been derived from the last range, and very few could be identified as coming from rocks 50 or 60 miles upstream.

Mr. WHITAKER did not see why the deposits should not have come from different directions in different localities; the pebbles were too widespread to have all come from the same district. He congratulated the Author on his attempt to solve the difficult problems dealt with in the paper.

Mr. H. W. MONCKTON remarked that, although it was possible that the pebbles in the Budleigh-Salterton and Bunter Pebble-Beds were derived from various sources, there was one constituent, the liver-coloured quartzite, which was of a singularly uniform character and had a very wide range. Also they sometimes contained fossils, more especially *Orthis budleighensis*. He thought that this rock was one well fitted to survive, and may have been handed on from one bed to another. He suggested that the liver-coloured quartzite-pebbles may have been worn into pebbles along some old coast-line, and have been derived from shingle-banks now wholly destroyed.

Mr. W. GIBSON said he did not think that the paper covered a sufficiently wide area. The Trias, he thought, should be studied as a whole.

Mr. A. E. SALTER stated that, after carefully studying a large number of Bunter pebbles, he had come to the conclusion that the quartzite-pebbles were of less value in indicating the source of origin of the beds in which they were obtained, than the much rarer pebbles of other rocks found associated with them. Several kinds of igneous rock were found, in addition to radiolarian chert with intricate secondary quartz-veining, and pieces of dark rock containing much tourmaline. The last two might very well have been derived from the South-West of England.

Prof. WATTS remarked that there was too great a tendency to judge the Bunter pebbles on the evidence of Budleigh Salterton and the Midlands, while a large intervening area remained unconsidered. A great factor, generally omitted, was that a pebble-bed extending over hundreds of square miles could not be paralleled with any contemporaneous deposit now being laid down. The only possible explanation was that the Bunter pebble-beds were not contemporaneous throughout the whole region. In short, the Triassic zones were not vertical, but horizontal.

After pointing out that several local types of rock were represented in the Bunter pebble-beds of the Midland area, the speaker said that our knowledge as to what underlies the Midlands is as yet fragmentary, but at all events it seemed difficult to believe that pebbles from Britanny or the Channel Islands could have got past

the now-buried Charnian range. He deprecated the citation of fossils or rock-types from the Drift, in connection with the Bunter pebble-beds.

Mr. H. H. Thomas said that local rocks were undoubtedly present in considerable degree in the district between Budleigh Salterton and the Somerset coast. The pebble-beds were not so thick as appeared at first sight, as there were considerable beds of sand interbedded with them. Part of the deposit was of southern origin.

Mr. Scrivenor said that he had found staurolite along the outcrop of the Bunter as far as Stourton, in Cheshire, and this mineral was common at Budleigh Salterton, but he did not think that any importance could be attached to this as bearing on the origin of the material.

Mr. A. P. Young said that, setting aside the question whether a big river could or could not have been the agent of transport, the great distance assigned for the source of the pebbles did not in itself bar the Author's hypothesis. The great terminal moraine (Baltischer Höhenrücken) of the North German plain was an instance in point. The distance over which the Scandinavian boulders were transported was of the same order of magnitude; and the abundance of the material was such that the quarrying of the moraine-ridges constituted a thriving industry.

The Author, in reply, said that he was glad to note that none of the facts advanced by him had been questioned. He had already anticipated some objections. The scope of the paper was limited by the title. He had done some little positive work, but he recognized how much still remained to be done. The palæontological evidence, so far as he had been able to present it, was highly important, and must be dealt with in any future investigations.

24. *On a* NEW SPECIES *of* *SOLENOPSIS* [*SOLENOMORPHA*] *from the* PENDLESIDE SERIES *of* HODDER PLACE, STONYHURST (LANCASHIRE). By WHEELTON HIND, M.D., B.S., F.R.C.S., F.G.S. (Read March 25th, 1903.)

SOLENOMORPHA, gen. nov.

Solen, pars, Goldfuss, 1832, in H. von Dechen's transl. of the 2nd ed. of De la Beche's 'Manual of Geognosy' p. 531.
„ Goldfuss, 1840, 'Petrefracta Germaniæ' vol. ii, p. 276.
„ Portlock, 1843, 'Rep. Geol. Londonderry, &c.' p. 441.
Solenopsis, M'Coy, 1844, 'Syn. Carb. Limest. Foss. Ireland' p. 47.
„ W. H. Baily, 1862, Explan. Sheet 127, Mem. Geol. Surv. Irel. p. 9.
Clidophorus, H. B. Geinitz, 1866, 'Carbonformation u. Dyas in Nebraska' p. 25.
Solenopsis, F. V. Hayden, 1871, Final Report of U.S. Geol. Surv. in Nebraska, p. 223.
„ L. G. de Koninck, 1885, Ann. Mus. Roy. Hist. Nat. Belg. vol. xi, p. 88.
„ Fischer, 1887, 'Manuel de Conchyliologie' p. 1112.
„ R. Etheridge, Sen., 1888, 'Brit. Foss. vol. i, Pal.' p. 291.
„ S. A. Miller, 1889, 'North American Geology & Palæontology' p. 512.
„ Beushausen, 1895, Abhandl. Königl. Preuss. Geol. Landesanst. n. s. pt. xvii, p. 216.
„ Hind, 1900, 'Monogr. Brit. Carb. Lamell.' pt. v, p. 412 (Pal. Soc. vol. liv).

Observations.—In 'Nature,' vol. lxvii (1903) p. 559, Prof. T. D. A. Cockerell points out that the name *Solenopsis* was adopted in 1841 for a genus of ants, and therefore must not be used for a genus of Mollusca; he suggests *Solenomorpha.* It is curious that the name has not been challenged since 1844.

SOLENOMORPHA MAJOR, sp. nov. (Fig. 1, p. 335.)

Specific characters. — Shell above the medium size, transversely elongate, ovato-lanceolate-truncate, very inequilateral, broad and convex in front, narrowed and compressed posteriorly, only slightly convex from before backward, more so from above downward. The anterior border is rounded, the inferior border prolonged and elliptically curved, the posterior short, bluntly obliquely truncate. The hinge-line is curved in front, long, and almost straight posteriorly. The umbones are obtuse, and placed in the anterior fifth of the valve. There seems to have been an elongate, narrow escutcheon.

Interior.—The anterior adductor-scar is large and rounded. Other characters and the hinge unknown.

Exterior.—The shell is ornamented with fine, close, concentric lines of growth, which follow the contour of the valve.

Dimensions.—Antero-posteriorly = 136 millimetres; dorso-ventrally = 42 mm.; gibbosity of valve = 5 mm.

Horizon and Locality.—Shales of the Pendleside Series, River Hodder, Hodder Place, Stonyhurst (Lancashire).

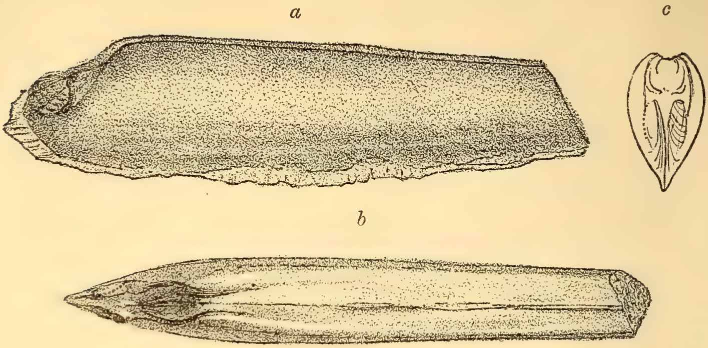
Observations.—This beautiful specimen was found by the Rev. Charles Hildreth, S.J., who has most kindly presented it to

the Museum of Practical Geology, Jermyn Street. The specimen is that of a perfect left valve, evidently a full-grown example, somewhat crushed along the hinge-line. The gradually-tapering posterior end and general shape point to the genus *Solenomorpha*, to which I now refer it without hesitation. *S. major* is so much larger, more compressed, and deeper than *S. minor*, that there is no danger of the two species being confused.

Fig. 1.—*Left valve of* Solenomorpha major, *natural size.*

I have described and figured two species of *Solenomorpha* in my Monograph of the Carboniferous Lamellibranchiata, vol. i, pt. v (1900) pp. 413–14 (Palæont.Soc.vol.liv). At that time I had unfortunately very poor material for study and illustration of *S. minor* and *S. parallela*, the two species described. I have since obtained a very fine, almost complete example of *S. minor*, from the Carboniferous Limestone of Yeat-House Quarry, near Frizington (Cumberland), which is figured here (fig. 2, p. 336), to compare with *S. major*. In this specimen, which is a cast of the interior, the anterior adductor muscle-scar is well shown, and also the broad upper surface of the shell, with a parallel groove on each side of the hinge-line.

Fig. 2.—*Cast of* Solenomorpha minor, *incomplete at the posterior end, natural size.*



a=View showing the interior of the left valve.
b=View from above, showing the cast of the hinge-line.
c=View of the anterior end, to show the diameter of the valve.

The shales of Hodder Place have yielded an interesting fauna. I have recognized in them the following organisms :—

Phillipsia Van der Grachtii.
Phillipsia Polleni.
Prolecanites compressus.
Glyphioceras spirale.
Glyphioceras reticulatum.
Glyphioceras platylobum.
Orthoceras annuloso-lineatum.
Posidonomya Becheri.
Solenomorpha major.
Also a few brachiopoda.

I do not think that the beds can be very far above the top of the Massive Limestone, a fact indicated by the presence of *Prolecanites compressus* and *Posidonomya Becheri.*

25. Geology *of the* Ashbourne *&* Buxton Branch *of the* London *&* North-Western Railway:—Crake Low *to* Parsley Hay.

By Henry Howe Arnold-Bemrose, Esq., M.A., F.G.S. (Read June 10th, 1903.)

[Plates XXII & XXIII.]

Contents.

I. Introduction.

In a previous paper read before this Society,[1] I gave a description of the geology of 6 miles of the new Ashbourne & Buxton Railway from Ashbourne to Crake Low. The sections described were in Bunter Sandstone, Boulder-Clay, shales and thin limestones (Yoredale Series of the Geological Survey), and volcanic tuff. The present paper is a continuation of the former one, and deals with the geology of the cuttings (Nos. 9 to 23) in the next 8 miles as far as Parsley Hay.

After passing through Yoredale Shales in the second cutting (No. 10), the railway enters the thick beds of Mountain-Limestone, in which it continues as far as Buxton. Several of the cuttings are of considerable length and depth; but, owing in some cases to the folded state of the beds, and in others to their nearly horizontal position, no very great thickness of limestone is seen.

It was not found possible to correlate the beds in the different cuttings. Although the limestones in the Cold-Eaton and Heathcote cuttings are somewhat similar in character and are divided up by intercalations of clay, we cannot be certain that they represent the same series of beds. The clay-partings do not in any way correspond. They are farther apart in the Cold-Eaton than in the Heathcote cutting. In the former six wayboards of clay are contained in 230 feet of limestone, and in the latter eight in a little more than 100 feet.

The chief points of interest brought to light by the sections in the cuttings are:

(i) The numerous folds into which the massive beds of Mountain-Limestone have been thrown on the western side of this part of the Pennine Chain.

[1] Quart. Journ. Geol. Soc. vol. lv (1899) pp. 224–36 & pls. xvii–xviii.

(ii) The granular and in part oolitic structure of some of the limestones.

(iii) The probable thinning-out of the volcanic tuff in a northerly direction from the village of Tissington.

The cuttings between Parsley-Hay Station and Buxton were completed before my attention was called to the new railway, consequently they have not been carefully examined. The dip of the limestones is generally small, and the cuttings are of no great depth nor length. In one of them, the vesicular lava which is mapped by the Geological Survey near Haslin House (about 1 mile south of Buxton) was seen north-west of Staker Hill.

II. Description of the Cuttings.

9. Crake-Low Farm.

Separated by a bank of red soil from the Crake-Low cutting (No. 8 in my previous paper) is one in which a thickness of about 30 feet of limestone is seen. The beds are contorted, and form a small fold the axis of which runs nearly due north and south. They consist of cherty limestones, which are often dolomitized and separated by thin partings of shale.

10. Newton Grange.

The railway has been cut through a ridge or elongated dome, which forms a well-marked feature in the landscape. The longer axis runs north-north-west and south-south-east, while the cutting is parallel to the shorter axis, and shows a section with a fine anticline in the Mountain-Limestone. For the first 80 or 90 yards the railway passes through shales and thin beds of limestone which are greatly contorted, then through a thick bed of limestone and alternations of shales and thin limestones, which mark the passage-bed from the Yoredale Series to the Mountain-Limestone. The dip is at first towards the east; with a few minor contortions, the beds roll over and settle to a south-easterly dip, which is maintained until we reach the centre of the dome, where the beds become horizontal, and then dip in a north-westerly direction.

The following measurements were taken from above downward. No attempt was made to measure or estimate the thickness of the contorted and rapidly-weathering shales at the southern end of the cutting. A well-defined bed of limestone, white and fresh on one side of the cutting, but brown and partly decomposed on the opposite side, was the topmost of the beds measured.

Section showing the junction of the Yoredale Beds and Mountain-Limestone at the southern end of Newton-Grange Cutting.

	Thickness in feet	inches.
Contorted shales, not measured	—	—
Limestone with *Productus*	2	0
Shale	0	10
Thin limestones and shales	3	0
Shale	2	6
Thin limestones with shale-partings	5	0
Do. Do. Do. (1045)[1]	4	0
Yellow tuff, the greater portion decomposed to a clay, but in places less weathered and blue in colour (1046)	6	0
Shale	1	3
Thin limestones	1	6
Soft black shale	2	3
Thin limestones	2	0
Shale	0	3
Limestone with *Productus*	1	4
Limestone and shale. One of the limestones thins out, and is replaced by shale a few feet away on the same horizon.	3	10
Laminated limestone (1047)	0	8
Shale	0	2
Fossiliferous limestone	0	6
Shale	0	2
Limestones with shale-partings	3	0
Shales, mostly black	9	0
Blue limestone (1049)	3	6
Chert-band	0	2
Blue limestones, with bands of chert and shale-partings	30	0
Blue limestone	4	0
Yellow limestone	1	0
Blue limestone and chert, with very thin shale-partings	16	0
Blue limestone with chert-band, shale almost absent	16	0
Blue limestone with chert-bands, lowest beds reached	28	0
Total thickness of beds seen	147	11

In the northern limb of the anticline the following beds were measured :—

	Thickness in feet.
Grey encrinital limestone, the encrinites being larger and more numerous near the top	47
Blue limestones with chert-bands	60
Total thickness of beds seen	107

The beds of limestone at the northern end of the cutting are, therefore, about 40 feet below the lowest of the shale-beds seen at the southern end. At the centre of the anticline the beds were seen

[1] The numbers in parentheses throughout this paper refer to those of the rock-slides in my collection.

to bend over in a south-easterly and north-westerly direction, and to dip at angles of 30° and 15° respectively.

No definite proof was found of volcanic detritus in the limestones associated with the shales above the Mountain-Limestone.

The bed of tuff, 6 feet thick, may represent the thinned-out portion of the tuff-bed that reaches a thickness of about 140 feet in the Tissington cutting. If this opinion be correct, the tuff in the cuttings nearer Tissington occurs on a horizon about 60 feet above the main mass of Mountain-Limestone; and, since the limestones for 80 feet above the thick tuff-bed contain volcanic detritus, volcanic action in this part of the country must have continued until between 100 and 200 feet of Yoredale rocks had been deposited.

11. Moat Low.

In this cutting, which is a short one, the beds dip 20° in a south-easterly direction. About 30 feet of limestone with bands of chert are seen. The beds in the immediate neighbourhood dip in the same direction as those in the cutting. In an old quarry east of the cutting and on the footpath to Parwich Lees encrinital limestones, with chert-bands in the limestones below them, are seen to dip south-eastward at an angle of 20°. In another old quarry, near O. D. 889·2, beds of massive limestone dip south-eastward at an angle of 30°. Near the 5th milestone from Ashbourne dolomitized limestones, with limestones containing *Productus* and encrinite-stems, are seen dipping south-eastward at an angle of 20°: while at the south-eastern end of the cutting and lower down the hill, cherty limestones are seen dipping 40° in a south-easterly direction. There is, therefore, a syncline between the Newton-Grange and Moat-Low cuttings, with its axis nearly parallel to the anticlinal axis of the Newton-Grange cutting.

12. New Inns (South).

In this cutting from 20 to 30 feet of limestone may be seen. The beds are at first nearly horizontal, and traversed by numerous calcite-veins. They then dip 20° in a north-westerly direction, and at the northern end are much broken up by joints, which are inclined at an angle of 50° to 90° to the horizon. These limestones contain encrinite-stems.

13. New Inns (North).

The beds consist of thin limestones which, on the whole, dip nearly due south or south-south-east, so that, as we proceed towards Buxton, we pass through successively lower beds in the series. There are a few small folds, and several good examples of lenticular beds of thicker limestone among the thinner ones.

14. Alsop-en-le-Dale. (See Pl. XXII, figs. 1 & 2.)

While this cutting was in progress, some very good sections of contorted strata belonging to the Mountain-Limestone were seen. Some of the best are now covered by a wall and a bridge, over which the turnpike-road passes.

The bearings of three of the anticlinal axes were taken, and found to be north-north-west and south-south-east, which is the same direction as the longer axis of the Newton-Grange dome.

The beds at first dip south-east by east, roll over in an anticline, and dip north-west by west; where the bridge has been erected they are bent into a sharp syncline and anticline. A sharp anticline follows, the beds then roll over into a more gentle anticline, are bent into a sharp syncline, and after passing through a short anticline and syncline, roll over a longer anticline and dip gently about 20° a little north of west. The beds contain chert, and are often dolomitized and traversed by veins of calcite; a fissure about 3 feet wide, on the south-western bank (down-line), is filled with clay.

Rough measurements of the beds show that a thickness of about 85 feet of limestone is seen in the cutting; and that, owing to the numerous folds into which the beds have been thrown, the difference in horizon of the beds at opposite ends of the cutting amounts only to about 10 or 15 feet.

15. Nettly Low.

This cutting is a small one, and only about 6 feet in depth. The beds dip as a rule nearly due east, towards the valley of the Dove.

16. Cold Eaton.

This cutting is in massive limestone with six clay-partings. The lower beds are at the Ashbourne end, and the dip is about 5° north-north-eastward. The lowest limestones below and up to the sixth or lowest clay-bed seen, consist of a white, granular and in part oolitic, limestone, with small pebbles of a previously-consolidated limestone. Other beds of limestone have the granular structure in most cases above and below a bed of clay. The clay-partings vary in thickness, and are sometimes variegated in differently-coloured layers. The upper beds of limestone contain a greater quantity of *Productus* than the lower, and are of a bluish-grey colour.

The following beds were measured:—

	Thickness in feet	*inches.*
Grey limestone, the upper parts containing *Productus* and passing down into a bluish-grey limestone. Dip 5° N.N.E. (1073)	110	0
First clay-parting, varying in thickness from 6 to 10 inches	1	5
Massive limestone	32	0
Carried forward	143	5

	Thickness in feet	inches.
Brought forward	143	5
Second clay-parting	0	6
Massive limestone, granular in places	86	0
Third clay-parting	1	4
Massive limestone, upper portion white (954); but granular above Clay No. 4	39	0
Fourth clay-parting	0	6
Massive limestone, granular below Clay No. 4 and immediately above Clay No. 5 (953 & 1074)	19	6
Fifth clay-parting, in about twenty-one layers varying in colour (1075)	1	10
Massive limestone, granular	22	0
Sixth clay-parting	0	8
Massive white limestone, granular, with a few specimens of *Productus*, encrinite-stems, and small pebbles of limestone	29	0
	343	9

17. Cheapside.

The beds in this cutting dip 10° to 15° south-south-eastward. The following section was seen:—

	Thickness in feet	inches.
Massive limestone	4	0
Clay-parting	0	5
Limestone	7	6
Encrinital limestone	5	6
Limestone, with stems of larger encrinites than those in the overlying bed	3	0
Limestone	10	0
	30	5

18. Bank House.

Only about 20 feet of strata can be seen in this cutting. The limestone is light-grey, with but a few traces of fossils. The beds are at first horizontal, and at the northern end dip 5° north-westward.

19. Heathcote.

At the southern end, and through a greater portion of the cutting, the beds dip 15° in a south-easterly direction, but at the Buxton end the dip decreases to an angle of 5°. There are several fissures, or pockets, in the limestone, filled with sand and clay. The sand is not a quartzose sand, but is probably derived from a decomposed dolomitic limestone.

The limestones in this cutting are, like those in the Cold-Eaton cutting, divided by wayboards of clay. They were not carefully examined for oolitic structure, as I was unable to visit the Heathcote cutting after I had found the oolitic limestones in the Cold-Eaton cutting.

The following beds were seen (the upper half was estimated, and the lower measured):—

	Thickness in feet	inches.
Limestones much broken up by joints .... about	25	0
Limestone with fossils .... about	40	0
Limestone with encrinites, dolomitized, and containing pockets filled with clay and decomposed dolomitic limestone .... at least	30	0
Massive limestone	40	0
First clay-parting	0	6
Limestone .... about	10	0
Second clay-parting	0	6
Limestone, granular (969)	30	0
Third clay-parting	0	5
Limestone	1	9
Fourth clay-parting	0	4
Limestone	8	0
Fifth clay-parting	0	6
Limestone	4	3
Sixth clay-parting	0	1
Limestone	12	0
Seventh clay-parting	0	6
Limestone	8	0
Eighth clay-parting	0	8
Limestone	30	0
	242	6

20. Hand Dales.

A thickness of about 30 feet of limestone was observed, the beds dipping 10° towards the Ashbourne end of the cutting.

The lowest beds consist of a white, finely-granular limestone (1092); above these may be seen 10 or 15 feet of a limestone containing encrinite-stems, a few shell-fragments, and other small fossils not yet determined. Above this limestone the beds contain a few corals.

21. Caskin Low.

A thickness of about 40 feet of horizontal beds is seen in this cutting. The upper beds are very much broken up and weathered, but the lower are more massive. The latter are dolomitized in the upper parts, and pass into very fine-grained limestones with foraminifera. The lowest beds seen are granular, and contain amorphous pellets, a few small pebbles of limestone, and small fossils not determined.

22. Lean Low.

This is a shallow cutting on the eastern side of the hill-slope, south of Parsley Hay Bridge. The beds are nearly horizontal, and although the cutting is about 500 feet long, only a thickness of 18 feet of limestone is seen. The rock is bluish-grey, and contains *Productus* and a few corals.

23. Parsley Hay.

This cutting is in a massive white or light-grey limestone. A thickness of about 66 feet of strata is seen. At the northern end of the cutting the beds dip 10° north-eastward, and contain a few corals. Near the bridge they become horizontal. A brown dolomitized limestone occurs in irregular patches, and in vertical vein-like masses. The latter are due to dolomitization of the limestone along vertical joints. A hand-specimen (1096) from a vertical joint shows the junction between the dolomitized and the ordinary limestone. The dolomitized portion is brown, the unaltered part grey. The grey limestone near the junction contains numerous brown spots which consist of rhombohedra of dolomite.

The middle beds near the northern end of the cutting yield foraminifera (1097).

III. Petrography of the Rocks.

(1) Calcareous Tuff in Newton-Grange Cutting.

Thin slice 1046 (see p. 339). This is a bluish-grey tuff similar to some parts of the thick bed of tuff in Highway-Close Barn, described in my previous paper.[1] The irregular outlines and vesicular structure of the lapilli are easily seen in a hand-specimen of the rock. In a thin slice there are many vacant spaces, owing to the lapilli having dropped out in the process of grinding. Some lapilli are, however, left in the thin slice, and are altered to calcite. This rock was originally a calcareous tuff, consisting of vesicular lapilli in a cement of calcite or in a sediment containing calcium-carbonate.

(2) The Limestones.

The limestones may be conveniently divided into:

(*a*) Crystalline limestones, either partly or wholly dolomitized.
(*b*) Fine-grained limestones, partly crystalline.
(*c*) Granular and, in part, oolitic limestones.
(*d*) Encrinital limestones.

(*a*) Some of the dolomitic limestones consist of a more or less granular aggregate of dolomite and calcite with few, if any, rhombohedral outlines.

A thin slice (973) from the New-Inns cutting shows clearly-defined rhombohedral crystals of dolomite, with patches of iron-oxide and a few quartz-grains.

The grey limestone near its junction with the brown dolomitized limestone in the Parsley-Hay cutting (1096) consists of clear crystalline calcite polarizing in bright tints, in which are embedded idiomorphic rhombohedra and segregations or patches of brown dolomite.

[1] Quart. Journ. Geol. Soc. vol. lv (1899) p. 233.

(*b*) The fine-grained limestones (1095, 1049, & 1073) consist mainly of more or less crystalline calcite, which contains small circular bodies (probably *Calcisphæra*), foraminifera, small fragments of shells, encrinite-stems, lath-shaped prisms of calcite with jagged edges, and a few quartz-prisms.

(*c*) Granular or Oolitic Limestones.

Several thin slices of the granular limestone from the Cold-Eaton cutting, and one from the Heathcote cutting, were examined.

Nos. 953 & 1074 were taken from the limestone a few inches above the fifth clay in the Cold-Eaton cutting (see p. 342). Examined with a lens in a hand-specimen, the rock is seen to consist of small grains and to contain small pebbles of limestone. Under the microscope, it consists of oolitic grains and pellets and well-worn pieces of limestone in a cement of calcite.

The oolitic grains possess a concentric, and sometimes a radial structure. In a few cases they show a black cross in polarized light, but the majority consist of a brown non-crystalline substance. They are generally circular or oval in section, and the nucleus often consists of a foraminifer or a shell-fragment. (See Pl. XXIII, fig. 1.)

The pellets are amorphous, and possess no recognizable structure. A few of them contain iron-oxide, and polarize in a grey tint. A similar substance forms the nucleus of one of the oolitic grains, and is very much like that of which the clay in thin slice 1075 is composed. Some of the pellets probably represent small portions of rolled clay, which have been incorporated in the limestone immediately above it.

The limestone-pebbles are well rounded, and contain foraminifera, fossil-fragments, and sometimes oolitic grains. They are often coated with a dark-brown amorphous substance, which is darker than the interior of the pebble. There is no doubt that they have been derived from a previously-consolidated limestone, and owe their well-rounded form to attrition. The oolitic grains, pellets, and pebbles are seldom in contact, but are cemented together by crystalline calcite. (See Pl. XXIII, fig. 2.)

No. 1076, below the sixth clay-bed in the Cold-Eaton cutting, and No. 969, below the second clay-bed in the Heathcote cutting, have a structure similar to the preceding, but are not in so fresh a condition. The majority of the oolitic grains either have been altered to a dark substance, or originally contained less calcium-carbonate. Amorphous pellets without any recognizable structure are present. The cementing-material is crystalline calcite.

The limestone above the fourth clay in the Cold-Eaton cutting is oolitic, but some feet higher in the series it loses its granular structure, and consists of shell-fragments, encrinite-stems, corals, and foraminifera (954).

(*d*) Encrinital Limestone.

Limestones with portions of encrinite-stems are common in the cuttings. They may be easily identified in hand-specimens, and in thin slices show the usual sections of these fossils.

(*e*) Clay-Parting.

(1075) A specimen of the soft clay from clay-parting No. 5, in the Cold-Eaton cutting (see p. 342), was kept in a drawer for several months. It was then sufficiently hard and dry for a thin slice to be made from it. Under the microscope it was seen to be amorphous, and contained iron-oxide. There were present a few needle-shaped crystals and prisms, with parallel extinction and positive double-refraction, polarizing in grey tints: these may be referred to quartz. Another small prism polarized in a yellowish-red, stood out in relief, had positive double-refraction, and may be assigned to zircon.

EXPLANATION OF PLATES XXII & XXIII.

Plate XXII.

Fig. 1. Anticline and syncline in Mountain-Limestone, Alsop-en-le-Dale Cutting, London & North-Western Railway. (See p. 341.)

2. Anticline in Mountain-Limestone, same locality. (See p. 341.)

Plate XXIII.

Fig. 1. Oolitic and pebbly limestone, $\times 50$, resting on the fifth clay-bed, Cold-Eaton Cutting, London & North-Western Railway. The oolitic grains show radial, and sometimes concentric structure. They are rarely in contact, and are separated by calcite, more or less crystalline, which exhibits very little structure or detail under the microscope (953). (See p. 345.)

2. Oolitic and pebbly limestone, $\times 25$, resting on the fifth clay-bed, same locality. The figure contains a pebble of fossiliferous limestone and small pellets (1074). (See p. 345.)

Discussion.

The Chairman (Mr. Teall) said that he was much pleased to know that the Author was continuing his excellent geological work in Derbyshire. In regard to the oolitic structures mentioned, he cited a paper recently published in the Neues Jahrbuch, where the results of an examination of recent oolitic grains showed that they were formed of aragonite, and so the inference had been drawn that all oolitic grains were aragonite to start with, and that the change to calcite had taken place in the process of fossilization. Moreover, it was found that if calcium-carbonate was precipitated from sea-water by the action of ammonium-carbonate on the calcium-sulphate spherules of aragonite were formed.

Prof. Sollas enquired whether the Author had discovered traces

Fig. 1.—Anticline and Syncline in Mountain-Limestone.

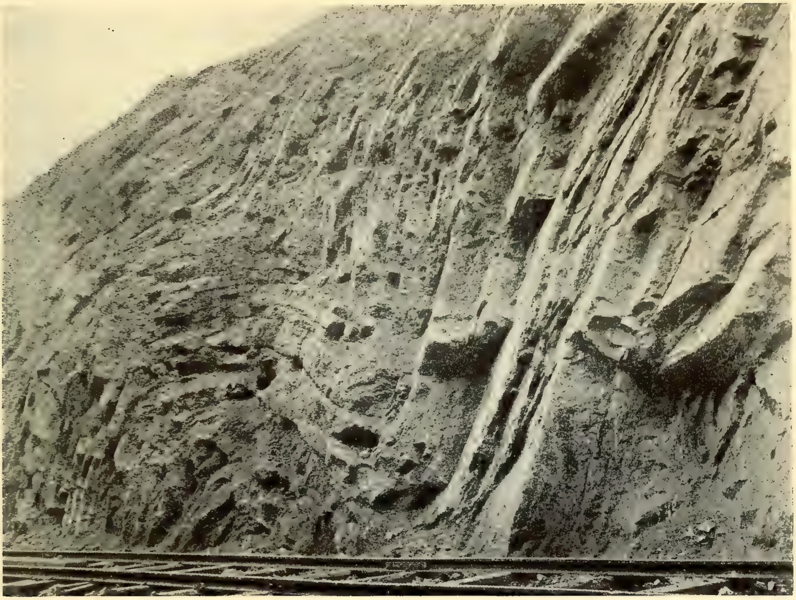
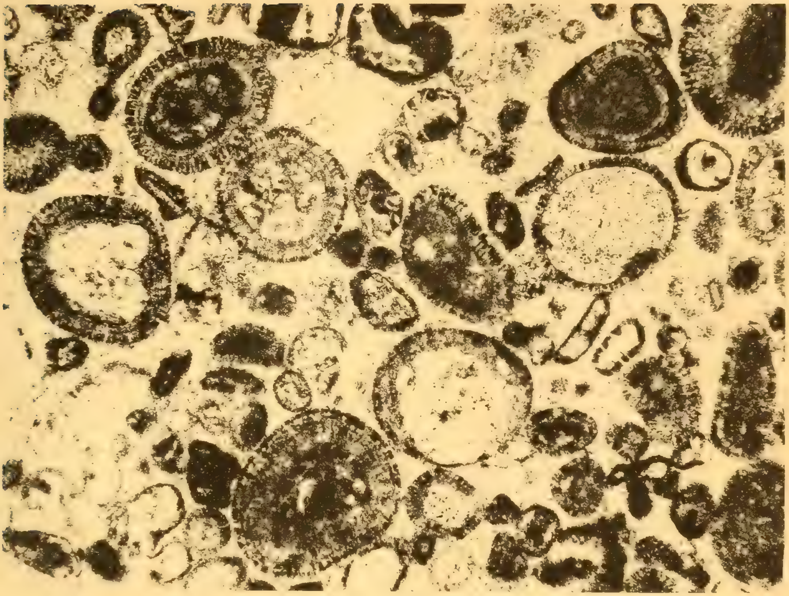


Fig. 2.—Anticline in Mountain-Limestone.

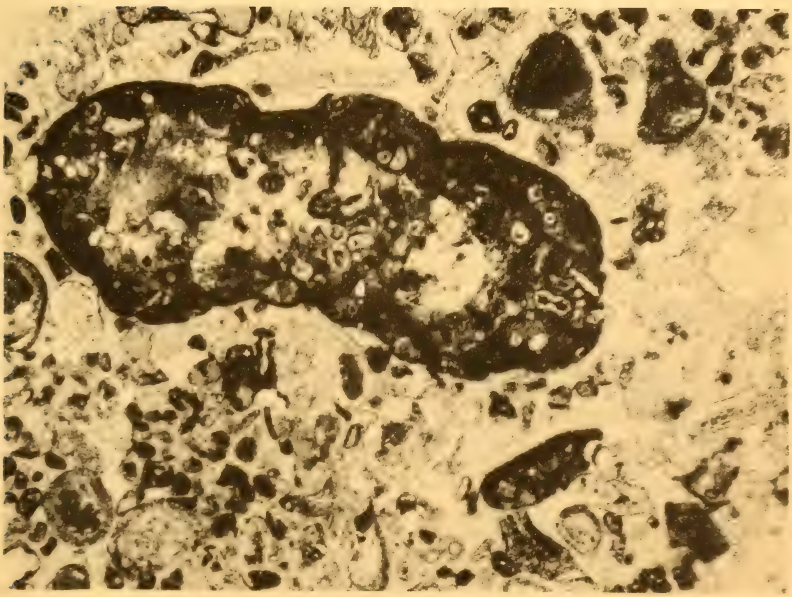
(*From Photographs by H. H. Arnold-Bemrose.*)

Fig. 1.



X50.

Fig. 2.



H. A. B., Photomicr.

X25.

Bemrose Ltd., Collo.

Oolitic and Pebbly Carboniferous Limestone.

of organisms among the oolitic rocks, and whether he attributed the oolitic structures to the growth of *Girvanella*. The best instances of oolite-formation at the present day occurred in closed salt-lakes ; he had never seen true oolitic structure in association with coral-reefs.

Prof. Watts said that he was much impressed by the Author's microphotographs of dolomitic limestone. There was no more remarkable phenomenon than the growth of dolomite in rocks of this kind. The magnesia appeared sporadically in the midst of oolitic grains, and there was a most interesting zonary arrangement of impurities inside the dolomite-crystals.

The Author said that encrinite-stems occurred in some of the oolitic grains, and thanked the Fellows for the reception accorded to his paper.

26. *An* Experiment *in* Mountain-Building. By the Right Hon. the Lord Avebury, P.C., D.C.L., LL.D., F.R.S., F.G.S. (Read May 27th, 1903.)

Many years ago Sir James Hall illustrated the formation of folded mountains by placing layers of cloth under a weight, and then compressing two of the sides so that the cloth was thrown into folds. Since then, other and more complete experiments of the same kind have been made by Favre, Cadell, Daubrée, Willis, and Ruskin.

In these experiments the compression was from two sides. If, however, folded mountains are caused by compression due to the contraction of the earth, the compression must take place in two directions at right angles one to the other.

With the view of illustrating this I consulted Mr. Horace Darwin, and he constructed for me an apparatus consisting of four square beams of wood, resting on a floor, which by means of screws could be moved nearer to, or farther from, each other. The beams left between them a space 2 feet across and 9 inches in depth.

In the square central space I placed some pieces of carpet-baize and layers of sand, each about $1\frac{1}{2}$ inches deep. About an inch above the upper layer of sand I placed a piece of plate-glass and some weights. The machine was then set in motion, causing the beams of wood to approach one another. The sand rose in the centre, until it reached the glass, when it was flattened out.

On removing the upper layer of sand, the top-piece of cloth was as shown in fig. 1 (p. 350), which is a photographic reproduction of a cast in plaster-of-Paris. The upper surface is gently undulating in the centre, with some steep folds near the edges and one slight ridge crossing the plateau at right angles to one of the folds.

On removing the underlying layers of sand, the next layer of cloth was as shown in fig. 2 (p. 350). There are two main lines of elevation; one running from each corner, and consequently crossing at right angles. The whole surface forms a series of winding and curving ridges with intervening valleys, and gradually rises to a culminating dome a little on one side of the centre, where the two main ridges intersect. I was rather surprised at the marked difference between this and the upper layer.

Underneath this second piece of baize was another layer of sand, on the removal of which the third layer of baize was found to be thrown into folds as in fig. 3 (p. 351). This again differed greatly from, though it evidently followed the same general law as, the preceding. The ridges are narrower and more pronounced, the valleys more precipitous. There is also a marked tendency for each ridge to present a central longitudinal division.

Fig. 4 (p. 351) represents a fourth layer of baize, which was separated from the third by about $1\frac{1}{2}$ inches of sand, and from the bottom of the apparatus by a similar layer. This fourth layer of baize differs from the third in somewhat the same manner as the third differs

from the second. The ridges are narrower, shorter, more precipitous, and more broken up. This characteristic is not, however, very well brought out in the photograph. The intervening spaces form wide, flat valleys.

In another experiment sand and layers of baize were arranged as before, but the weight was placed on one side, in consequence of which the material was more easily pressed up.

In this case the ridges followed the edges, though not closely, leaving a central hollow. Here, also, in the upper layer of cloth (fig. 5, p. 352) the slopes were more gentle, the eminences more rounded, the hollows less deep. In the second layer of cloth (fig. 6, p. 352) the country is more rugged, the elevations higher, the hollows deeper. Here too several of the ridges have a tendency to become double, with in some cases a smaller ridge commencing in the depression. The elevations and hollows only follow roughly those of the upper layer. There are two main ranges, with a broad intermediate valley. One of the main ridges has secondary transverse folds.

The third layer (fig. 7, p. 353) again has only a general resemblance to the second. The folds are more numerous, narrower, and more precipitous.

The fourth or lowest layer (fig. 8, p. 353) presents a central plain, bounded by two high, one moderate, and one low, series of hills.

The models seem also to show that some hollows, which might on the earth's surface have been regarded as evidence of sinking, are in reality only relative, and due not to depression, but to the elevation of surrounding ridges.

I am proposing to make further experiments with various modifications, which at some future opportunity I hope to be permitted to lay before the Geological Society.

Discussion.

The Chairman (Mr. E. T. Newton) said that the fact that the subject of the paper was one to which the President had given so much attention, would all the more cause the Fellows to regret his absence and the reason that gave rise to it.

Mr. Hudleston disclaimed any special knowledge of the subject, but wished to draw attention to a particular feature shown in the models, which, as he understood the Author, had been mentioned in his explanation. This was the more acute accentuation of the foldings in the lower part of the series. So far as his (the speaker's) experience extended, this peculiarity might be noticed in certain mountain-ranges. There is an excellent example in part of the Jhelum Valley in the Outer Himalayas, where all the beds are of one formation, namely, Middle Tertiary, and where it is easy to perceive that the lower beds, close to the river, are often vertical and extremely contorted, while higher up the angle of inclination lessens, and towards the top there is a simple anticline of moderate

Fig. 1.

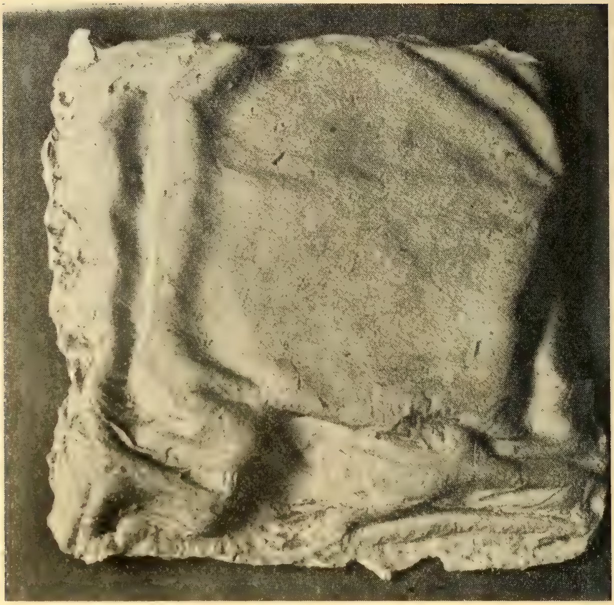


Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

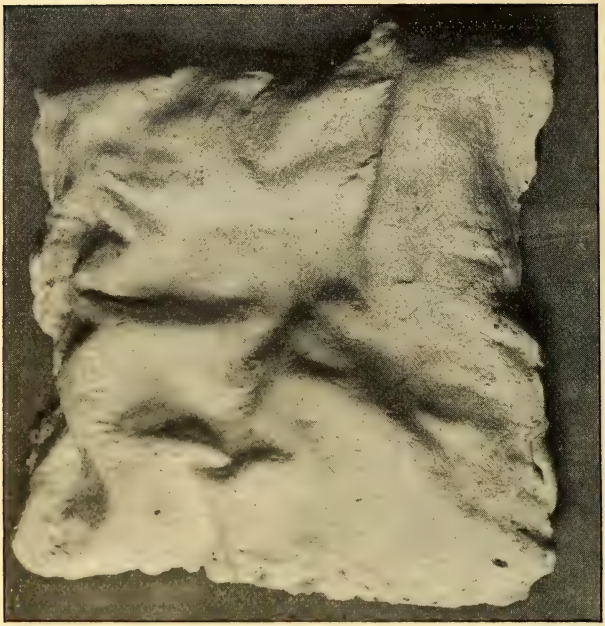


Fig. 6.

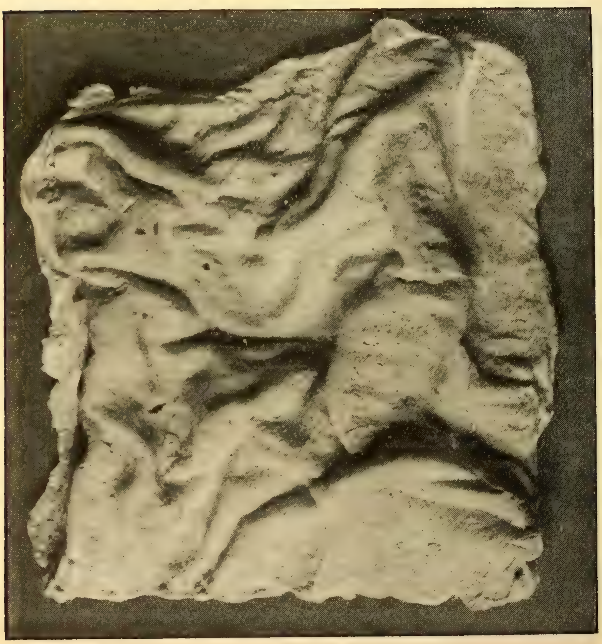


Fig. 7.

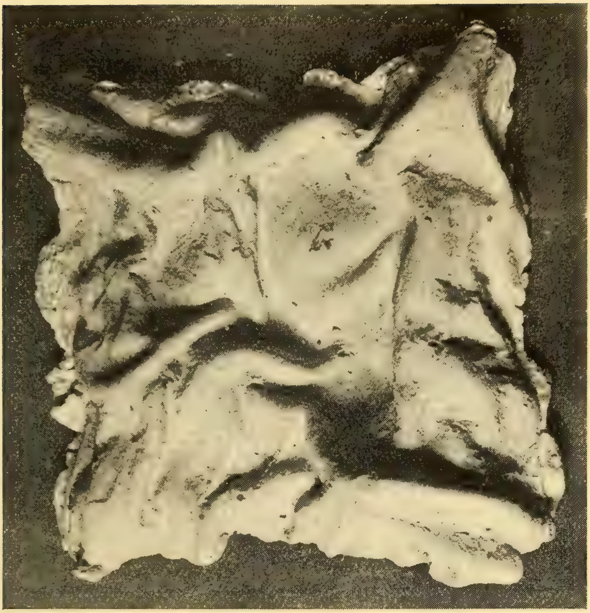


Fig. 8.

dip. Generally speaking, one might say that in mountains of recent date, such as the Outer Himalayas, and even the Pyrenees, contortions are not particularly in evidence, while the higher beds are simply tilted, though sometimes at a very high angle. The case is different in regard to the older ranges, such as those of Scotland and Wales, which, being merely stumps of a mountain-chain, exhibit chiefly the lower features.

Mr. P. F. Kendall said that these experiments were very suggestive, and he hoped that the Author would persevere with them. He would like to see the vertical scale much reduced, so that the number of folds might be increased; it would, he thought, also be desirable to make some provision for a diminution in the rigidity of the materials forming the deeper-seated layers, so as to imitate more closely the conditions prevailing in the lower portions of earth-folds. He should like to see some experiments made with contracting circles, which might perhaps throw light upon the structure of curved mountain-chains. He thought that the North-Western Highlands were far too complex in structure to constitute a suitable study of mountain-folding, and would prefer to take as an example some widespread deposit the folds of which could be traced with precision over a large area. The Chalk of the South-East of England appeared to show the phenomena of cross-folding with great clearness, and there was a major wave or fold indicated by the general dip to the south-east, and transverse ripples forming the decussating folds of the Isle of Wight, the Portsdown anticline, the great Wealden anticline, and others.

Mr. Rudler welcomed the Author's suggestive researches, as making a great advance on the work of earlier experimentalists in the same field. By applying stresses in two directions at right angles one to the other, it seemed possible to simulate the effects resulting from the intersection of two rectangular sets of folds, such as the Caledonian and the Charnian. He foresaw a wide range of possibilities in these ingenious experiments, by varying the magnitude of the pressure and the character of the media operated on, and especially by varying the weight of the load under which the substance was subjected to strain.

Dr. Johnston-Lavis thought that some attempt to adhere to ratios such as they existed in Nature would give more value to the experiments. He would suggest that artificial loads should be replaced by thicknesses of the material compressed, proportional to the probable average thickness of the earth's crust. At the same time, the compression should be proportional to what is known to have taken place in the Alps or other mountain-chains. The compression should be slow, and some artificial denuding rain, such as water with plaster or clay, or weak hydrochloric acid with cement, should be used to represent erosion simultaneous with mountain-building. Compression should be tried, not only at right angles as in the Author's experiments, but also with the axes of compression at other angles, and moreover compression should be applied simultaneously and also consecutively. This would, to

a great extent, represent the conditions prevailing on the earth's surface at different localities and periods.

If these researches were being carried out by himself, he would use a roughened sheet of rubber attached to a ring, stretched over the top of a cylinder, and, after being charged with the materials of the experiment, allowed to contract. In fact, the arrangement would be similar to that used for stretching parchment-drumheads. He cordially thanked the Author for reviving a question that had of late been neglected, but which would be likely to afford much interesting information.

He would not terminate without warning experimenters that the lower part of the earth's crust may be far more plastic from heat than had been allowed for in earlier experiments, which would explain the great crumpling of the deeper parts of disturbed areas.

Prof. J. W. Spencer thought that some of the models showed resemblance to structures produced in the West Indian islands by denudation, and he compared another with a Mexican plateau.

The Rev. J. F. Blake said that he was much interested by one of the models exhibited, which showed the production of an elevated isolated plateau or 'horst,' about the origin of which there had been much discussion abroad. In attempting to account for one in a particular instance, he had been led to the conclusion that if strata bent into a syncline between two anticlines were afterwards bent in a direction at right angles, so that a new anticline crossed the old syncline, such a form of ground would result, and he was glad, therefore, to see this conclusion experimentally confirmed when the conditions happened to be suitable.

Mr. Whitaker said, in regard to the materials used in the experiments, that cloth was excellent for folding only; but, to show fracture as well, some other material would have to be used. He suggested also the application of a slight upward pressure, as well as lateral pressures. He pointed out that in one set of the casts the centre was a hill, and that in the other set it was a hollow.

Mr. H. W. Monckton referred to the folded rock now seen at the surface of the ground, and said that he would much like to have some idea as to the amount of strata which had been removed from above the folded rock since the folding took place. The Author's experiments threw light on this question, and seemed to suggest that although folds might be produced near the surface, the more marked folding was produced by pressure at some depth, though perhaps not at so great a depth as was at one time supposed.

Dr. J. W. Evans suggested that the experiments might be repeated with a local load on some part of the surface, so as to imitate the effects on folding of the accumulation of sedimentary strata on the flanks of a mountain-chain.

The Author expressed his thanks for the complimentary remarks, and the valuable suggestions, which had been made.

27. *On a* SHELLY BOULDER-CLAY *in the* SO-CALLED 'PALAGONITE-FORMATION' *of* ICELAND. By HELGI PJETURSSON, Cand. Sci. Nat. (Communicated by Prof. W. W. WATTS, M.A., Sec.G.S. Read April 29th, 1903.)

IT is a fact well worthy of note that, while the basalt-formation of Iceland bears, geologically, a very close resemblance to the basalt-plateaux of the British Isles, the Tertiary volcanic phenomena of this latter region present nothing strictly analogous to the great tuff- and breccia- or so-called 'palagonite-formation' of Iceland. For it is obvious that the fragmental materials of the British volcanic region, which are intercalated with the basaltic lavas and only of 'trifling thickness,'[1] cannot have their geological equivalent in the great palagonite-formation of Iceland, which covers thousands of square miles, and in isolated patches is met with over a greater part of the total area of the island.

The palagonite-formation has been in several respects a puzzle to the geologists who have visited Iceland: some have been of the opinion that the tuffs and breccias are contemporaneous with the plateau-basalts or even older; but the more systematic investigations of Prof. Th. Thoroddsen have shown that in reality the fragmental masses are younger than the basalt-formation.[2] Prof. Thoroddsen thinks that towards the close of Tertiary time the central parts of Iceland were buried under a continuous covering of fragmental volcanic materials 3000 to 4000 feet thick, which formation was broken up into single mountain-masses and isolated fells before and during the Glacial Period.[3]

In the summer of 1899 it was observed that very considerable masses of ground-moraine are intercalated with the breccias which constitute hills rising out of, or bordering, the southern lowlands of Iceland[4]; and in subsequent years observations in distant parts of the country brought out the same general result, namely, that there exist in Iceland extensive traces of intense glacial action, older than those known to geologists before 1899, and that we are fully justified in speaking of a 'Glacial palagonite-formation.'[5]

The breccia-formation of the peninsula of Snæfellsnes, which I investigated in the summer of 1902, like that of other parts of the

[1] Sir Archibald Geikie: 'The Ancient Volcanoes of Great Britain' vol. ii (1897) p. 194.

[2] See, for instance, Prof. Thoroddsen's 'Vulkaner i det nordöstlige Island,' Bih. t. K. Svensk. Vet.-Akad. Handl. vol. xiv, pt. ii (1888), no. 5, p. 68.

[3] Thoroddsen, Dansk. Geograf. Tidsskr. 1898, p. 2 (sep. cop.).

[4] Helgi Pjetursson: 'The Glacial Palagonite-Formation of Iceland' Scot. Geogr. Mag. vol. xvi (1900) pp. 265–93; & 'Nyjungar i Jardfrædi Islands Eimreidin' 1900, pp. 52–57 (Icelandic).

[5] Helgi Pjetursson: 'Moræner i den islandske Palagonitformation,' Overs. Kgl. Danske Vidensk. Selsk. Forhandl. 1901, pp. 147–71; & 'Fortsatte Bidrag til Kundskab om Islands "glaciale Palagonitformation"' Geol. Fören. i Stockholm Förhandl. vol. xxiv (1902) pp. 357–69. This last paper embodied a few observations made during the summer of 1901.

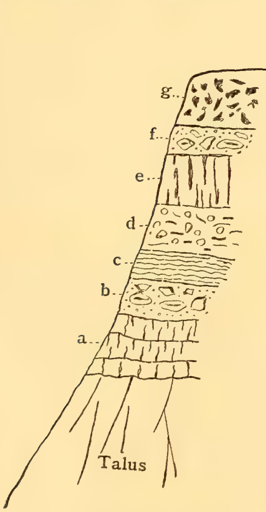
country, is built up chiefly of palagonitic tuffs and breccias, conglomerates (in part probably fluvio-glacial), and moraines. But, while in other parts of Iceland the rule is that, owing to subsidence, the basement of the breccia-formation has been hidden from view, in Snæfellsnes, on the contrary, the basaltic basement of the breccias, etc., can very commonly be seen.

The Tertiary basalts of the peninsula, however, are also traversed by faults and very clearly have subsided; and in the eastern portion of the cliffs of Olafsvíkur-enni—a basal part of the great volcanic pile of Snæfellsjökull (4710 feet)—the 'fundamental basalt' has even disappeared below sea-level, while farther west it again appears, reaching however barely to a height of 100 feet above the sea.

Now, the basement-layer of the breccia-formation is seen in many places to consist of a greyish, indurated ground-moraine, varying in thickness, and containing glaciated basaltic blocks of all sizes up to 6 feet or more in diameter. Thus in the above-mentioned cliffs of Olafsvíkur-enni, the fundamental basalt is succeeded above by an indurated ground-moraine, which in turn is overlain by a thickness of probably more than 1000 feet of tuffs, breccias, conglomerates, and probably also morainic deposits.

It is more profitable, however, to turn to the plateau of Mávahlíd, which projects in the promontory of Búlandshöfdi. Here the escarpment can be scaled in several places, and every single layer of a section examined. The following diagram from the western face of the escarpment may perhaps be taken to represent the normal mode of composition of this plateau (fig. 1).

Fig. 1.—*Section of the plateau of Mávahlíd.*



g = Volcanic tuffs and breccias.
f = Indurated ground-moraine, with striated stones, 30 feet.
e = Columnar basalt.
d = Conglomerate, about 40 feet.
c = Tufaceous sandstone, 20 to 30 feet.
b = Indurated ground-moraine, about 40 feet.
a = Fundamental basalt, reaching to about 400 feet above the sea.

The fundamental basalt (*a*) differs in colour, in texture, and in its

often being amygdaloidal and decomposed, from the sheets of basalt which are interbanded with the 'breccia-formation.'

The moraines (*b*) and (*f*) are of a bluish-grey colour, and contain numerous distinctly-striated stones of various sizes.

The volcanic breccias of different kinds and colours, from nearly black to yellowish-brown, attain—on both sides of the section exposed—a thickness of probably not less than 300 feet, and their maximal thickness is even much greater, for in places the breccias of the plateau rise into hills several hundred feet high. These breccias are not post-Glacial, for erratics and loose glacial rubbish are commonly found strewn over their surface.

Some little distance from the farm of Mávahlíd, the sheet of columnar basalt (*e*), with the overlying moraine and the underlying conglomerate (*d*), is well seen; while the lower moraine can hardly be distinguished from the conglomerates, and the fundamental basalt only appears in the corrie towards the left. On the right, volcanic breccia, which thickens southward, is seen overlapping the upper moraine.

Nevertheless, interesting as are the sections briefly described above, showing as they do that Glacial conditions existed here at a time when the contour and relief of the region differed very greatly from what is now the peninsula of Snæfellsnes, they are surpassed in interest by a section near Búlandshöfdi, on the northern face of the escarpment, where is clearly exposed a shelly Boulder-Clay, reaching a height of more than 600 feet above the sea and buried under hundreds of feet of conglomerate, lava, and volcanic breccias ('palagonitic breccias'), which show a glaciated surface (erratics and loose glacial rubble).

The succession of the beds is shown in fig. 2 (p. 359).

The top of the shelly Boulder-Clay (*b*) reaches a height of rather more than 600 feet above the sea,[1] and its total thickness is 70 to 80 feet. The clay is indurated, shows no stratification, and through it are scattered numerous blocks of basalt of various sizes, hardly exceeding, however, 8 inches in diameter. Some of the boulders are angular, others rounded; many, especially of the bigger blocks, are so well polished and striated that they could serve as beautiful types of glacier-stones.

This Boulder-Clay is more interesting than others of the moraines of the 'palagonite-formation' by reason of the shells, which occur in very great numbers throughout the whole thickness of the bed (*b*), with the exception of some 10 feet of laminated sandy clay (β) towards its base.

The shells are, as a rule, highly triturated, unbroken specimens

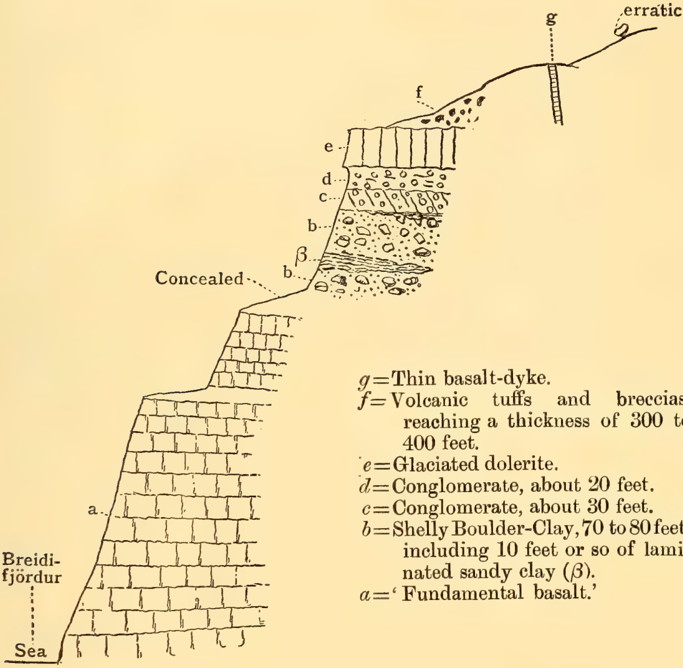
[1] This, even though the shells are of derivative origin, must probably be taken as evidence of a much greater submergence of the country than was previously suspected. The highest level at which a marine fossil had been found was about 200 feet above the sea. This was a *Balanus*, obtained in 1899 in a bank of the Thjórsá, in marine clay probably corresponding in age to the later *Yoldia*-beds of Scandinavia.

being very rare. The malacologist of the Zoological Museum of Copenhagen, Hr. Ad. S. Jensen, who has been good enough to undertake the determination of the fossils in question, has sent me the following list of species :—

Astarte borealis, Chemn.
Portlandia lenticula, Möll. (?), nucleus.[1]
Leda pernula, Muell., nucleus.
Mya truncata, L.
Saxicava arctica, L.
Trophon clathratus, L.

Of the foregoing species, *Astarte borealis* is the shell most commonly met with in our Boulder-Clay, and next to it in abundance

Fig. 2.—*Section near Búlandshöfdi.*



g=Thin basalt-dyke.
f=Volcanic tuffs and breccias, reaching a thickness of 300 to 400 feet.
e=Glaciated dolerite.
d=Conglomerate, about 20 feet.
c=Conglomerate, about 30 feet.
b=Shelly Boulder-Clay, 70 to 80 feet, including 10 feet or so of laminated sandy clay (β).
a=‘Fundamental basalt.’

are *Saxicava arctica* and *Mya truncata*. Hr. Jensen calls attention to the great thickness of the valves of the two last-named species,

[1] [Hr. Jensen is now of opinion that this is a nucleus of *Portlandia (Yoldia) arctica*, Gray. A shepherd-boy from Mávahlíd, Helgi Salómonsson, whom I took to the locality and requested especially to look out for such things as this nucleus, later collected, besides other shells, three specimens of *Portlandia arctica*, Gray, which have been kindly determined by Hr. Jensen. These are :—

(1) A specimen with both valves, partly crushed, but certainly recognizable by its sculpture.

(2) A nucleus with some remains of the valves; the foremost end is broken off, but the specimen has probably been at least 22 millimetres long.

(3) A nucleus (the valves still partly preserved) about 16 mm. in length.—*June 25th, 1903.*]

as indicative of cold (Glacial) conditions. In fact, the above-named six species of molluscs are among those found in the Scandinavian deposits of the *Yoldia*-sea; and it can hardly be doubted that here too they lived in an icy sea before they got into the ground-moraine of an advancing glacier—which took place before the eruption of the 'pre-Glacial dolerites' of Prof. Thoroddsen and others. On Prof. Thoroddsen's new geological map of Iceland, published in 1901, the doleritic lavas are shown as pre-Glacial and Glacial; while on his special maps published before 1900 they are shown only as pre-Glacial. As a matter of fact, they are largely inter-Glacial, or at any rate inter-morainic.

A discussion of the facts alluded to above, and many others connected with them, must be deferred until I am able to give a fuller account of the investigations which I carried out in 1901 and 1902; only a few points may be here briefly mentioned.

I take it to be an unquestionable fact that the basement-layer of the 'breccia-formation' of Snæfellsnes is a ground-moraine; and in other parts of the country beds of indurated ground-moraine are found very deep in this formation, buried under hundreds of feet of rock—not to say more. Now, I do not mean to contend that the shelly Boulder-Clay of Búlandshöfdi is necessarily of the same age as the lower moraine of other sections of the Mávahlíd-plateau (fig. 1), but we learn from this section (fig. 2) that at least some of the older moraines ('palagonite-moraines') are of Pleistocene age.

I do not believe that the tuff- and breccia-formation ever had an average thickness of 3000 or 4000 feet, but rather that the fragmental materials have been piled up to this great thickness around centres of eruption only. Indeed, I imagine that, on further examination, it would not be difficult to point out a considerable number of the wrecks of the volcanic cones of the breccia-formation; although I must confess that I did not recognize any of them until the summer of 1902, after I had had occasion to see the quite unmistakable remnant of such a volcano near Kerlingarskard, Snæfellsnes.[1]

It is highly probable that further research will tend to confirm the hypothesis, not only that volcanic activity continued uninterruptedly in Iceland during the Glacial Period, but that it was of great intensity, especially perhaps towards the beginning and the close of a glaciation, and that the eruptions, unlike the fissure-eruptions of pre-Glacial and in part also of recent times,[2] resulted to a great extent in the building-up of bulky hills of scoriæ and ashes, some of which have survived the Glacial Period as volcanoes (and are still covered with snow and ice, and belching forth, not lava, but scoriæ and ashes); while others have become extinct and

[1] It ought perhaps to be mentioned here that Prof. Thoroddsen wrote in 1898 in regard to Súdur (Dansk. Geograf. Tidsskr. vol. xv, p. 11): 'Perhaps we have here the wreck of a volcano dating from the close of the Tertiary Era.'

[2] See Sir Archibald Geikie's 'Ancient Volcanoes of Great Britain' vol. ii (1897) chap. xl.

their materials have in part gone to make up the 'palagonite-moraines.'

In short, I think that the evidence of the Snæfellsnes sections lends a strong support to the view that the palagonite- or breccia-formation of Iceland, is volcanic and glacial, resulting from the action and the interaction of both causes, and corresponds—at any rate, to a very considerable extent—in age to the Pleistocene deposits of Europe: the glaciated doleritic lavas ('pre-Glacial dolerites') representing the most marked of the inter-Glacial epochs.

And here we have returned to the question raised at our starting-point: Is it not possible that the absence of a palagonite-formation in Great Britain may be ascribed to the fact that there the volcanic fires had become extinct before the setting-in of Glacial conditions?

In conclusion, I desire to express my heartiest thanks to Mrs. Disney Leith, of Westhall (Aberdeenshire), who has been kind enough to give a most necessary polish to my somewhat angular mode of expression.

Discussion.

The Chairman (Mr. Teall) remarked that the Author had set forth his facts well and clearly, and the conclusion to which they inevitably pointed—namely, that the palagonite-formation was, at all events in part, contemporaneous with the Glacial Period—was of very great interest.

28. *On* SOME DISTURBANCES *in the* CHALK *near* ROYSTON (HERTFORDSHIRE). By HORACE BOLINGBROKE WOODWARD, Esq., F.R.S., F.G.S. (Read May 13th, 1903.)

ON the Geological-Survey map (Sheet 47, old series) a 'line of flexure' is marked in the Chalk-area from Therfield,[1] south-west of Royston in Hertfordshire, to near Heydon in Cambridgeshire,[2] a distance of rather more than 6 miles. The line is a curved one, and in three places to the north of it, and in one to the south, arrows are engraved on the map to indicate that the Chalk dips northward or north-north-westward at angles varying from 22° to 60°. It may be noted that the line of the flexure is drawn, not at right angles to the directions indicated by the arrows, but a little below the crest of the Upper Chalk-escarpment, which has here been eroded in a broad semicircular hollow; and that it is continued east of Heydon as the 'approximate line of division between the Upper and the Middle Chalk.'

The late W. H. Penning, who surveyed the area, called attention to the flexure in 1876,[3] when describing some ancient 'river-gravels' which lie in the vale to the north, but he did so only incidentally, remarking on its post-Eocene age, and expressing his opinion that the upper extremity of the Wardington valley—the semicircular hollow before mentioned—was due to this flexure in the Chalk. Particulars of the sections, with illustrations of those near Reed and Barkway, were published two years later in the Survey Memoir.[4] Therein Penning (p. 11) stated that

'The flexure appears to have been very local, and of no great vertical extent. It occurs so near the top of the escarpment that all evidence of the lower part of the curve seems to have been obliterated by the denudation of the range. Still, as there are no signs of Upper Chalk, but Chalk without flints occurs in all exposures at a lower level, it is probable that just below the level of the pits the beds begin to resume their horizontality.'

With a dip of 60° there is here some demand on the imagination.

The general structure of the area, although not free from small faults, is otherwise quite normal; and Penning rightly observes (*loc. cit.*) that

'As a rule the Chalk lies very evenly, being either horizontal or dipping slightly to the south-east.'

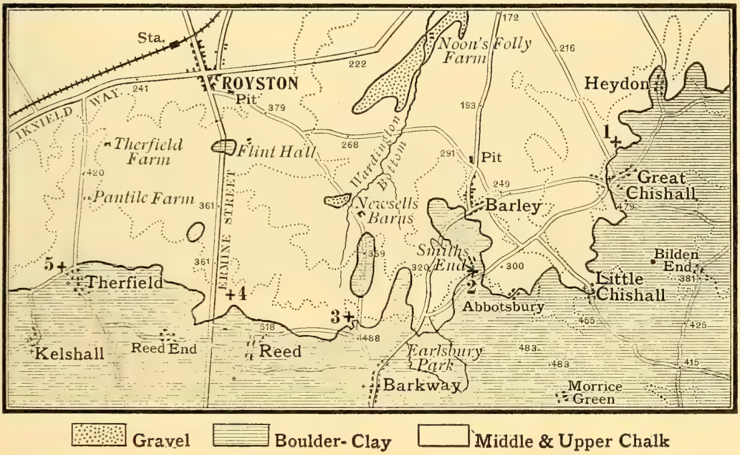
The sequence, in fact, is regular from the low-lying tract of Chalk-Marl, worked so extensively for cement-making at Shepreth, through the Totternhoe Stone, the outcrop of which is marked here and there by copious springs, and through the overlying grey blocky Chalk or 'clunch' to the Melbourn Rock of Melbourn. Then comes

[1] Therfield, on the 6-inch map; Tharfield, on the old 1-inch map.
[2] Until recently in Essex.
[3] Quart. Journ. Geol. Soc. vol. xxxii (1876) pp. 196, 197, 200.
[4] 'The Geology of the North-West Part of Essex & the North-East Part of Herts, &c.' Mem. Geol. Surv. (1878) pp. 7–11.

the Middle Chalk, which forms a scarp to the south, and rises up in the picturesque undulating tract of the Royston Downs. It is well exposed in large pits south of Royston, beyond which the dip-slope has been hollowed into a broad undulating vale bounded by the region of disturbance. (See map, fig. 1.)

Along the crest of this higher ground, which rises from 400 to a little over 500 feet, the Upper Chalk is capped by Boulder-Clay; this descends southward across the eroded Chalk, and follows the dip-slope into the London Basin. The Chalk-Rock may be traced here and there below the crest, but it extends farther north than represented on the Geological Survey-map near Heydon, as observed

Fig. 1.—*Geological map of the neighbourhood of Royston, based on Sheet 47 of the Geological Survey-map.*



[Scale: 1 inch=2 miles.]

Note.—The bigger numerals indicate the chalk-pits described in this paper; the smaller numerals the altitudes in feet; and the dotted lines indicate the contours.

by Mr. Whitaker, and it likewise extends farther north at Barley. It was clearly injudicious on the part of those who made the map to connect the line of disturbance with the outcrop of the Chalk-Rock, although in truth it follows close upon it in a general way.

It was during a series of traverses made in this region in the spring of 1900, and after an examination of a part of the disturbed area, that I was led to question the explanation of the flexure given by Penning; and I ventured to remark in an article on the Geology of Essex,

'Whether the disturbance is due to faulting or to the surface-derangements produced by Glacial agents has not been satisfactorily determined.'[1]

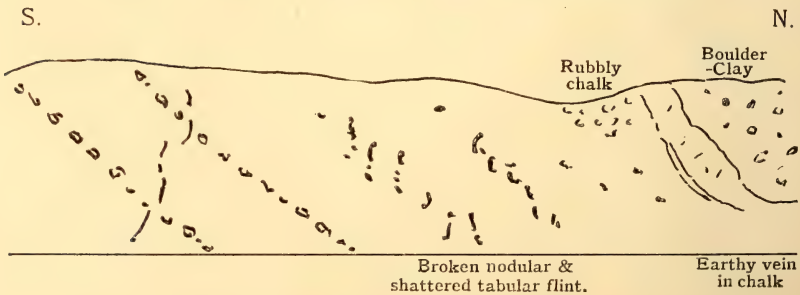
It was not, however, until the autumn of last year that I again

[1] 'Victoria History of the Counties of England: Essex' vol. i (1903) p. 5.

Fig. 2.—*Chalk-pit at Pinner's Cross, Smith's End, Barley.*

[From a photograph by J. J. H. Teall, Esq., F.R.S.]

Fig. 3.—*Section at Pinner's Cross, Smith's End, Barley.*



[Scales, vertical & horizontal: 1 inch=16 feet.]

had an opportunity of visiting the district; and then, having examined the four pits where the high dips are marked on the Geological Survey-map, I found evidence which satisfied me that the disturbances were due to glacial action—a view confirmed on a subsequent visit during the present year.

The four sections are as follows, proceeding from east to west.

(1) Great Chishall.

The pit here lies to the north of the village, and the 400-foot contour-line passes through it. It has not been worked for some years, and is a good deal overgrown. There was no indication of any definite dip. A few large flints and broken tabular layers were observed. Much of the Chalk was broken and shattered, and near the surface this portion was weathered into rounded lumps. At one spot the interspaces had been filled with ochreous earth, and on the exposed face the chalk-lumps stood out in relief, scored and furrowed by downwashes of rain and mud, so as almost to simulate the Boulder-Clay with its glaciated chalk-stones, which on the northern side of the pit rested upon the Chalk.

This weathered Chalk is of some interest, as from such material, and especially from weathered rounded portions of the Chalk-Rock and harder beds of the Middle Chalk, much of the Chalk-detritus in the Boulder-Clay was no doubt to a large extent derived.

I could find no evidence of the high dip recorded by Penning. All he says (*op. cit.* p. 10) is that

'In the pit north of Great Chishall Church the lines of bedding dip apparently 25° N. by W., this being on the line of flexure already noticed.'

(2) Pinner's Cross, Smith's End, south of Barley.

Here in a pit by the roadside, 387 feet above sea-level, Chalk is exposed with two well-marked bands of nodular flint, about 6 feet apart, dipping northward at an angle of about 40°. Farther north in the pit there are evidences in the Chalk of what were formerly two other flint-bands, but are now a mixture of broken nodular and tabular flint and flint-chips, the fragments of tabular flint having an approximately vertical position. Still farther north, the Chalk presented at the surface the rubbly weathered aspect elsewhere observed, and banked against it was 6 feet or more of Chalky Boulder-Clay. The Boulder-Clay stones were mainly Chalk, many glaciated, also Oolite, quartz-pebbles, etc. Here the icy agent had evidently pressed against the Chalk, bending it in mass and shivering and streaking out the flint-layers.

The note on this pit in the Geological Survey Memoir is by Mr. Penning & Mr. Whitaker.[1] The Chalk with flint-layers is stated to dip north by west 40° to 45°, and Boulder-Clay was observed in a hollow in the north. No mention is made of the shattered Chalk, which probably was not then opened up.

[1] 'The Geology of the N.W. Part of Essex & the N.E. Part of Herts, &c.' Mem. Geol. Surv. (1878) p. 7.

Fig. 4.—*Chalk-pit, south-west of Newsell's Park and north of Barkway.*

[Indications of differential movements in the Chalk are seen in this figure.]

Fig. 5.—*Boulder-Clay beneath Chalk, in the pit south-west of Newsell's Park and north of Barkway.*

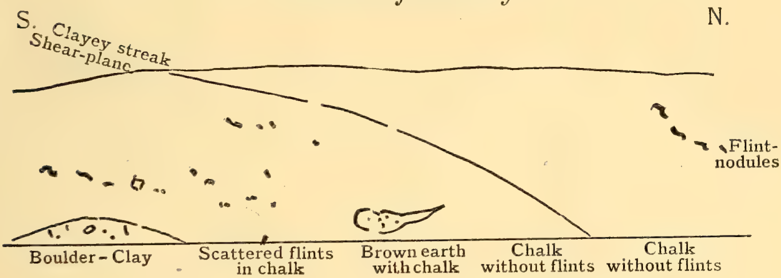
[Both the above figures are reproduced from photographs by J. J. H. Teall, Esq., F.R.S.]

(3) Lime-kiln, south-west of Newsell's Park and north of Barkway.

Here we find from 20 to 30 feet of Chalk exposed in a large pit, about 440 feet above sea-level. It is difficult to see any orderly arrangement in the Chalk. There is, towards the southern end, an irregular undulating band of scattered flints, and an occasional gall of brown clay may be noticed near the base of the pit. Near the base also, and about midway, is an irregular mass of brown earthy and chalky material—shattered Chalk with earthy matrix. A grey clayey streak beyond extends in a curved direction from the top to the bottom of the pit. This might have been taken as an indication of dip, but it is probably a shear-plane, as the character of the Chalk differs along what otherwise would be the bedding-planes, and thus indicates displacement. There appears to be a portion of a flint-band in the northern part of the pit.

All doubt about the nature of the disturbance was removed by the fact that below an overhanging portion of the Chalk, in the

Fig. 6.—*Section at the lime-kiln, south-west of Newsell's Park and north of Barkway.*



[Scales, vertical & horizontal: 1 inch = about 32 feet.]

southern part of the pit, there is an exposure of 4 feet of brown and greyish-brown Boulder-Clay,—similar in character to that elsewhere noted, a mass of which also occurs in this pit on the north-eastern face. In the Boulder-Clay beneath the Chalk glaciated pieces of chalk occur, and two phosphatic nodules from the Cambridge Greensand were found.

From this pit the illustration (fig. 2, p. 8) in the Geological-Survey Memoir was taken. It shows a regular succession of curved beds of Chalk, and, as observed by Messrs. Penning & Whitaker (*op. cit.* p. 7):

'The dip increases to about 60°, being well shown by four distinct layers (hard beds, marl, and flints).'

The following is their record of the section (*op. cit.* p. 8):—

'*a.* Whitish Boulder-Clay; occurs in a hollow at south-west corner.
b. Upper Chalk, with scattered flints.
c. Chalk-Rock. Hard cream-coloured crystalline chalk, irregular beds, 2 to 2½ feet thick. The chalk between with a thin layer of marl and a broken-up layer of flint-nodules.
d. Lower Chalk (*Inoceramus*, *Scalpellum*, etc.).

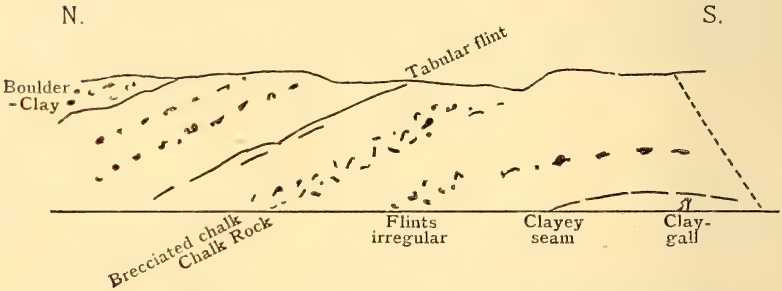
No doubt the pit has been considerably enlarged since that section was recorded, and other features have been made manifest; but I cannot help thinking that the illustration drawn by Penning was what the Rev. J. F. Blake would call an 'interpretation-section,' rather than an actual representation, because the picture does not strictly accord with the explanation: for instance, the scattered flints in the Upper Chalk are shown as a continuous band of nodules, in the midst of even bands of Chalk.

(4) North of Reed, east of the main road, about 2 miles from Royston. [This chalk-pit is 500 feet above sea-level.]

Here, at first sight, we seem clearly to have an ordinary gentle anticlinal disturbance.

The beds appear to arch over slightly towards the south, and there is a small dislocation. A thin clayey seam occurs in place towards the base of the pit, and in the Chalk below is an irregular

Fig. 7.—*Section north of Reed.*



[Scales, vertical & horizontal: 1 inch = 44 feet.]

gall of brown clay. Regular bands of flint, both nodular and tabular, appear at higher horizons dipping northward.

The lowermost of the bands becomes broken towards the north. At some little distance above it is a band of shattered Chalk-Rock, the mass for 3 or 4 feet in thickness having the appearance of a chalk-breccia, or of broken beds. Still higher up there is a thin continuous layer of tabular flint, showing slight irregularities.

Boulder-Clay occurs at the northern end of the pit; and both here and at Smith's End, Messrs. Penning & Jukes-Browne observed that this drift rested 'on a surface of the beds nearly parallel to their stratification,' as if 'the disturbing force had acted on the beds in post-Glacial times.'[1]

[1] 'Geology of the Neighbourhood of Cambridge' Mem. Geol. Surv. (1881) p. 67.

This pit was figured by Penning, and my own notes are in practical accordance with his. The pit has been worked farther to the south, and the evidence of the arching over of the strata in that direction is now apparent.

There is a fifth pit a little west of the cross-roads north of Therfield, about 530 feet above sea-level; and this showed Chalk-with-flints having a slight northerly dip, with Boulder-Clay banked up against the upper part on the northern side. Here we have a final indication of the local disturbance.

The fact that the Chalk is bent into a gentle anticline at Reed, combined with other evidence, enables us to feel confident that elsewhere the Chalk was similarly ridged up, and that nowhere are the highly inclined strata overturned or inverted, though there may be an overthrust in the Barkway pit. That the Chalk is so bent and the flints in places so shattered might of course be due to subterranean disturbance, as in the faulted and fractured Chalk of the Purbeck coast, were it not that the disturbed Chalk near Royston, with its fractured and displaced flints, occurs in conjunction with the Boulder-Clay, and that we have a mass of Boulder-Clay beneath a considerable thickness of disturbed Chalk.

No other explanation is reasonable, and in my opinion none other is possible, than that the Chalk was disturbed by the agent which formed and distributed the Chalky Boulder-Clay.

If I followed the dictates of prudence I might perhaps stop here, but I am tempted not to leave my story without an end.

It has been noted that Boulder-Clay occurs along the crest of the high ground bounding the disturbed area, and in force to the south; but excepting on the spurs of this high ground, which extend beyond the line of disturbance, the vale and undulating downs immediately to the north are devoid of this Glacial Drift. This is a remarkable fact, when we remember that in East Anglia (as Penning observes) the Boulder-Clay 'caps the highest hills' and sometimes 'occupies the deepest valleys.'[1] There are broad hollows below the Upper Chalk-scarp, in one or two instances, with somewhat narrower outlets opening to the north, and calling to mind dwarfed forms of corries. One such hollow may be noticed 6 furlongs north-east of Therfield Church; and a wider amphitheatre-like expanse, of which mention has previously been made, opens out west of Barley, and is prolonged through Wardington Bottom.

The question arises as to whether a portion of the ice at the time of maximum glaciation was arrested over the lower grounds, while higher masses of ice were thrust forward against the scarp, bending the Chalk and fracturing and disturbing its flint-layers, portions of the ice finally overriding the crest and extending towards the London Basin.

[1] Quart. Journ. Geol. Soc. vol. xxxii (1876) p. 195.

I am not stopping to discuss what some may still consider a debatable subject, the character of the agent which formed and distributed the Chalky Boulder-Clay. That this agent was land-ice, in the opinion of most of those who have lived and laboured on the Drifts, is supported by overwhelming evidence.

Penning rejected the land-ice theory of the Boulder-Clay, especially because he found no signs of grinding or thrusting of the surfaces beneath that Glacial deposit.[1]

The local evidence is now forthcoming; and it is unnecessary to do more than mention the similar cases of disturbed Chalk near Trimingham and near Norwich, not to mention other formations more or less disturbed beneath the Chalky Boulder-Clay in various parts of the Midland and Eastern Counties, and the evidence of dislodged and transported masses of Chalk and other strata.

Attention, however, may be recalled to the disturbed Chalk at Litcham in West Norfolk, described in 1866 by S. V. Wood, Jun.[2] There he noticed that the lower flint-layer exposed in a chalk-pit was bent into a gentle anticline, and the layers above were greatly ruptured, and even overthrust. Wood attributed the disturbance to land-glaciation. He noted also the presence of galls of brown clay in the disturbed Chalk, and while observing that they had no connection with pipes or pot-holes, he was unable to offer an explanation. Similar pockets of clay occur in the disturbed Chalk of Royston, and the section in pit No. 1 (Great Chishall, p. 365) affords a clue, as it indicates that fine earthy material may be carried into chinks of the ruptured Chalk by rain-waters.

The features, therefore, to which attention has been directed are such as are familiar elsewhere, and may be ascribed to a common cause: that of widespread glaciation. Nor need we be at a loss to conceive in a general way what that glaciation was, while bearing in mind that the main features of the country were sculptured in pre-Glacial times.

Inspired by the observations and deductions of American geologists —of Messrs. T. C. Chamberlin, W. Upham, W. O. Crosby,[3] and R. D. Salisbury—we may regard the process of accumulation of the Chalky Boulder-Clay as bereft of many difficulties; and this without disrespect to the prophets in this country. We have but to picture a large area, a humid climate, and a mean annual temperature of a few degrees only below freezing-point. We have no need to raise up mountains of rock if we raise up accumulations of snow and ice, for ultimately the pressure from the thickness of the mass would initiate movement without the aid of thrusting by ice from higher grounds.

The base of this ice-sheet would be welded by means of ice to the more or less weathered and rubbly surface-strata beneath; and when movement took place, the frozen surface-deposits at the base,

[1] Quart. Journ. Geol. Soc. vol. xxxii (1876) p. 195.

[2] *Ibid.* vol. xxiii (1867) p. 86.

[3] I am especially indebted to a paper by Mr. W. O. Crosby, of which I prepared an abridgment in the Geol. Mag. for 1897, p. 319.

as pointed out by Mr. Crosby, would be rent asunder from the more solid unfrozen beds beneath. The detritus was moved with the ice, as he and others have explained,[1] as an englacial drift, and not as a ground-moraine. It was set free as a ground-moraine by the melting-back of the ice, during temporary, or after final, retreat; an accumulation thus liable to be overridden and pressed into the exceedingly-tough stony clay which is the usual character of the Chalky Boulder-Clay. Inequalities of the ground led to overthrust in the mass of the ice, and detritus that had been basal was thus carried to higher levels. The rock-fragments, such as fractured flints and lumps of chalk, were rubbed together along shear-planes in the ice, causing the chalk-lumps and other rocks to be scored and flattened as we find them. Much of the Boulder-Clay being blue in colour, was torn from unweathered clays, the soil having been removed perhaps prior to the advance of the ice, but this not in all cases.

That the ice advanced from a northerly direction and impinged against the Chalk-hills, may be conceded without doing any violence to the imagination. That higher portions of débris-laden ice overrode lower portions that were arrested by inequalities in the ground, may be assumed. Much ice was doubtless for long stopped by the higher Chalk-scarp; and to the thrust or long-continued pressure of ice along shear-planes at higher levels against the crest of the scarp, we may attribute that belt of disturbance which occurs at elevations of 387 and 400 feet on the east, and 535 feet on the west.

The débris-laden ice was eventually pushed far and wide beyond the limits of the Chalk-scarp, planing off the higher portions of the Upper Chalk and carrying material as far as the Thames Valley near Hornchurch.

Penning and others have commented on the distribution of the Middle Glacial gravels and sands which underlie the Boulder-Clay along the dip-slope of the Chalk south of the crest, and are overlapped towards the summit. There these gravels occur up to a height of 300 feet or more, and quite 200 feet above the bottom of the valley to the north, where no Middle Glacial Drift is recognized. Finding no evidence of its former presence and subsequent erosion in this area, Penning was led to conclude that the Middle Glacial Drift was confined to the seaward side of the Chalk-ranges.[2] Locally, there appears much in favour of this view; and we might even regard the Glacial gravels within the London Basin as the modified Drift or moraine of the earliest invasion of the ice, and before it extended on to the Tertiary tracts of Essex and Hertfordshire.

There are, however, some patches of gravel in the broad valley of Wardington Bottom, to which Penning drew special attention.[3]

[1] See also J. G. Goodchild, Geol. Mag. 1874, p. 501.

[2] Quart. Journ. Geol. Soc. vol. xxxii (1876) p. 197. References are there given (p. 201) to papers by S. V. Wood, Jun.

[3] *Ibid.* pp. 199–200. See also Jukes-Browne, 'Post-Tertiary Deposits of Cambridgeshire' [Sedgwick Prize Essay for 1876] 1878, p. 46.

They

'occur at an elevation of 20 to 60 feet, or thereabouts, above the level of the river, and consist of gravels and sands with intercalated masses of loam and clay, the latter having somewhat the appearance of Boulder-Clay, or, rather, of a wash from Boulder-Clay in its immediate vicinity.'

He thought that

'all the phenomena might occur as well, either in an esker or in deposits left by a river of tolerable magnitude.'

He concluded that the deposits marked the course of an ancient river, while admitting that they might have been

'formed during the removal by denudation of the Boulder-Clay which once filled the valley.'

We can readily believe in this derivation of the material, even if we hesitate to accept the view that the deposits mark the actual course of an ancient river.[1] The melting of the ice which occupied this valley, the lower portion of which had been for long banked up against the scarp, was doubtless attended by powerful currents which distributed the débris, and even tore away a good deal of Chalk from the scarps.

We may thus consider that the outlines of the combes, to which attention has already been directed, were largely sculptured at this period; and we might go some way with Sedgwick when he remarked in 1861 that these lesser features in the Chalk

'do not appear to have been produced by a long-continued and slow process of erosion; but rather to have been cleanly swept out by rapidly-descending water-floods.'[2]

Postscript.

Mr. A. J. Jukes-Browne writes to me as follows:—

'What you tell me about that curious flexure along the Royston Downs is very interesting. Penning was much puzzled by it, as is clear from what he wrote on p. 67 of the Memoir on the Neighbourhood of Cambridge. I only saw the sections once, and in company with him. It is of course quite possible for Boulder-Clay to be forced into and between beds of Chalk *in situ*. Do I understand that you attribute the whole disturbance, for a distance of more than 5 miles, to the impact of ice? It seems a large order!'

Discussion.

The Rev. E. Hill welcomed the chronicle of facts, but thought that rather a large superstructure was built upon them. Disturbances were described under Boulder-Clay, but in many cases absence of disturbance could be seen, and equally required explanation. Trimingham was quoted as a parallel: there Boulder-Clay over Chalk looks undisturbed, while sands over the Clay are contorted.

[1] Some terrestrial and freshwater mollusca were found in gravels, regarded as equivalent, in the area to the north of that now under consideration. See 'Geology of the Neighbourhood of Cambridge' Mem. Geol. Surv. (1881) pp. 82, &c.

[2] 'A Lecture on the Strata near Cambridge & the Fens of the Bedford Level' 8vo [privately printed] p. 37.

Mr. WHITAKER said that, if his former colleague, the late Mr. Penning, were alive, he would probably accept the views put forward by the Author. Mr. Penning and he had chronicled the facts as they saw them, and they could not at that time attempt the division of the Chalk in the same detail as is possible nowadays. Moreover, they were working on the old 1-inch map.

Prof. SOLLAS agreed with the Author in attributing the disturbances to pressure exerted by ice. It was probable that with the progress of investigation similar disturbances would be found in other localities, and they might even become recognized as an evidence of glacial action in districts where other evidence, such as Boulder-Clay, was absent. On the flanks of Shotover Hill, near Oxford, a local inversion of the Corallian on the Kimmeridge Clay, and of the latter on the Portland Sands, may be observed: the inversion is associated with a thrust-plane which, where it affects the Kimmeridge Clay, is beautifully slickensided. On Cumnor Hill, situated about 6 miles to the west of Shotover, and on the other side of the Thames Valley, Miss Healey has lately found a similar inversion; a long tongue of Kimmeridge Clay is here thrust over the iron-sands, and the overlying Pleistocene gravels are involved in the movement. Here again the thrust-planes are slickensided, and the clay exhibits a kind of foliation similar to that which gives the characteristic 'tea-leaf' structure to some Boulder-Clays. Mr. Montgomery Bell has found similar but less marked disturbances in the Oxford Clay, also affecting the overlying Pleistocene gravels, and producing 'tea-leaf' structure in the clay. It was intended to bring a detailed account of these and similar disturbances before the Society on another occasion; in the meantime, they were mentioned as offering a confirmation of the Author's explanation.

The Rev. J. F. BLAKE drew attention to a description and figure which he had given, in vol. v of the Proceedings of the Geologists' Association, of some locally-upturned Chalk in Yorkshire; this he had no hesitation at that time (1877) in ascribing to the action of ice. He enquired how the buried Boulder-Clay described by the Author was supposed to have reached its present position.

Mr. F. W. HARMER said that he was much interested in the paper just read, especially as it seemed to confirm the views enunciated by Searles V. Wood, Jr., many years ago, as to the origin of the Chalky Boulder-Clay. It had been often held that the ice to which the latter was due came from the North Sea over North-Eastern Norfolk. That this was not so is shown by the fact that no Chalky Boulder-Clay exists between Cromer and Norwich, though it comes on suddenly to the south of that city. If, on the contrary, it came from the north-west, as Wood believed, fanning out from the Fenland region in all directions, it would be in the neighbourhood of the latter, where the ice lay thickest, that disturbance of the underlying Chalk, similar to the cases described by the Author, would be met with. In Eastern Suffolk, where the ice was thinner, it would have had less erosive power. In that district it overrode the Middle Glacial Sands, and, as a rule, without disturbing them.

It did not there cut down to the Chalk or the Eocene beds, except in the valleys. It is worthy of notice that the valleys of East Anglia, speaking generally, radiate from the Fenland region like the divisions of a fan. To a considerable extent they have been excavated, or deepened, in Glacial times, and may represent gigantic striæ, and the direction of the ice-flow. He quite agreed with Sedgwick's opinion that combes (and, he thought, gorges also) were due to floods, rather than to slow erosion. In Italy, from which country he had just returned, there has been an extraordinary amount of post-Pliocene denudation. The Italian geologists with whom he had discussed the subject were all strongly of opinion that this denudation could only have taken place under meteorological conditions of much greater intensity than those of the present time. The evidence for a 'pluvial' period is very strong in the South of Europe.

Prof. Groom said that it appeared difficult to explain the remarkable disposition of the Jurassic beds at Shotover Hill, shown to him by Prof. Sollas, on the hypothesis of ordinary tectonic movements; thrust by moving ice seemed to afford the best explanation.

The Author remarked that the subject of the mode of glaciation must be dealt with in a large way. As an instance of land-glaciation he referred to a section on the Great Central Railway north of Brackley, where Great Oolite with its rubbly top and brown soil were covered by Boulder-Clay, while farther north the rubble and soil had been swept away, the Great Oolite was directly covered by Boulder-Clay, and in this Drift were streaks of brown soil from the old land-surface. He referred also to the remarkably-even scarp of the Lincolnshire Limestone, and to the absence of outliers in advance of it, as possibly due to glaciation, the results of which were found in the large transported masses of Jurassic limestone, described by John Morris and Prof. Judd, in the area to the south. In his experience the evidences of disturbance beneath the Boulder-Clay were abundant, and he could not in this respect agree with Mr. Hill.

With regard to the observations of Prof. Sollas and Prof. Groom, he thought that their 'Pleistocene gravel' might be newer than the Boulder-Clay, but Boulder-Clay did occur, not so very far off, to the north of Bicester and Grendon Underwood.

In answer to the Rev. J. F. Blake, he remarked that shear-planes in the ice were probably numerous, and it was not difficult to imagine a mass of débris-laden ice being thrust under a disturbed portion of Chalk. In the pit near Newsell's Park the Chalk was much shattered, and in the underlying Boulder-Clay he had found Cambridge coprolites and Lower Greensand, as well as glaciated Chalk.

29. *On a* Transported Mass *of* Ampthill Clay *in the* Boulder-Clay *at* Biggleswade (Bedfordshire). By Henry Home, Esq. (Communicated by Horace B. Woodward, Esq., F.R.S., F.G.S. Read June 24th, 1903.)

The section to be described has been exposed in the construction of a well, which is being sunk into the water-bearing strata of the Lower Greensand, about 2 miles south-south-east of Biggleswade Railway-station, and less than half a mile north of Bleak Hall on the western side of the Roman Way. The excavation down to the 70-foot level was about 14 feet in diameter, and below that depth about 10 feet.

The section is as follows (see also fig., p. 376):—

	Thickness in feet.	*Depth from surface in feet.*
1. Agricultural soil	2	2
2. Boulder-Clay	8½	10½
3. Dark indigo-coloured clay	67	77½
4. Chalky Boulder-Clay	6	83½
5. A bed in the Boulder-Clay drift	10½	94
6. Passage-bed to Gault	7½	101½
7. Gault-Clay	7½	109
8. Lower Greensand to the level of 180½ feet, not bottomed.		

Bed No. 1 calls for no remark.

Bed No. 2 contains well-striated boulders and fossils, chiefly belemnites and *Gryphææ* of the Oxford Clay and Lower Lias.

Bed No. 3: thickness 67 feet. On the excavation entering this bed it was seen that the clay had not the characteristics of the Gault. It was a dark indigo-coloured selenitiferous clay, laminated, and becoming shaly on exposure to dry weather. A large number of septarian nodules occurred throughout it, some in regular layers parallel to the bedding of the clay, and others irregularly.

One layer of which special notice was taken, situated at a depth of 37 feet from the surface, dipped west-south-westward at an angle of 9°. Some of these septarian nodules had an area of as much as 20 square feet and weighed about 2 tons. They nearly all contained water. The characteristic fossil that was found throughout the greater part of this bed was *Ammonites (Cardioceras) excavatus*, which occurs also in a pyritized form. *Thracia depressa* too was present at all levels.

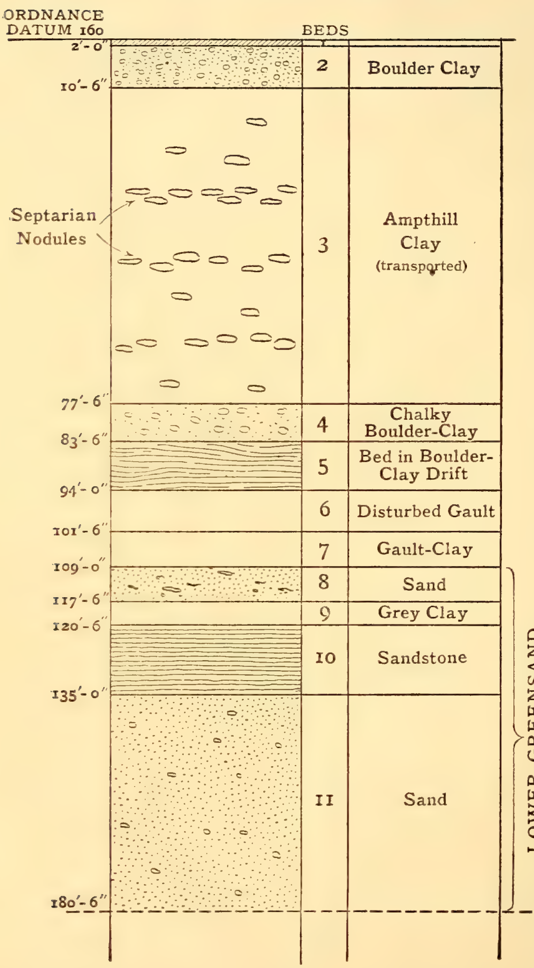
The following fossils obtained from this bed, between the depths of 10½ and 77½ feet, were identified by Mr. E. T. Newton, F.R.S.:—

Ammonites (Cardioceras) excavatus, Sow.
Ammonites (Perisphinctes) varicostatus, Buckl.
Belemnites allied to *Panderi*, d'Orb.
Belemnites cf. *nitidus*, Dollfus.
Gasteropod.
Nucula sp.
Pleuromya recurva, Phil.
Pleuromya recurva, Phil. (small form).
Protocardium sp.
Trigonia near to *clavellata*, Sow.
Trigonia near to *triquetra*, Seeb.
Ostrea deltoidea, Sow.
Ostrea discoidea, Seeley.
Thracia depressa, Sow.
Serpula tetragona, Sow.

These fossils indicate that we have here a great mass of Ampthill Clay, which has been removed from the parent-mass. If we compare this bed with the Ampthill Clay as known *in situ*, we find that :—

(1) It is lithologically identical, both being dark clays with selenite-crystals. Although the presence of selenite-crystals is of little value taken alone (selenite being met with in the Kimmeridge Clay and to a much less degree in the Oxford Clay, the crystals being due to exposure and oxidation), the occurrence is yet of some significance, as pointed out by the late Thomas Roberts.[1]

Well-section near Biggleswade.



(2) The occurrence of *Ammonites excavatus* is common to the Oxford, Ampthill, and Corallian Clays, but that form is not mentioned as occurring in the Kimmeridge Clay. Many of the ammonites were covered with *Serpulæ*, as elsewhere observed in the Corallian Beds, and their presence would indicate a slow rate of deposition. Were the basement-beds of the

[1] Quart. Journ. Geol. Soc. vol. xlv (1889) p. 550 ; and 'Jurassic Rocks of the Neighbourhood of Cambridge' [Sedgwick Prize Essay for 1886] 1892, p. 36. See also H. B. Woodward, 'Jurassic Rocks of Britain vol. v Mem. Geol. Surv. (1895) p. 137.

Kimmeridge Clay present, we should expect *Ostrea deltoidea* in numbers, although it is not characteristic of the Upper Kimmeridge Clay.

Bed No. 4, 6 feet thick, was made up of a stiff, whitish-brown Boulder-Clay, with about 20 per cent. of chalk. Most of this chalk was in the form of a fine powder; but there were also many pieces of glaciated chalk, some measuring as much as 6×4 inches, and flints.

Bed No. 5, $10\frac{1}{2}$ feet thick, consisted of a fine silty clay, with chalk in its upper portion. It contained a few flint-boulders, many pieces of glaciated septaria, Oolitic limestone, and sandstone-grit formed of quartzite and glauconite cemented together, very similar to the grit at Bourn (Cambridgeshire), north-east of the well. This portion of the Drift was evidently a sedimentary deposit, probably a glacier-mud.

Bed No. 6, $7\frac{1}{2}$ feet thick. This was the disturbed upper portion of the Gault, and contained many examples of *Belemnites minimus* and a number of specimens of *Inoceramus concentricus*.

Bed No. 7, $7\frac{1}{2}$ feet thick, depth $101\frac{1}{2}$ to 109 feet, is true fossiliferous Gault-Clay, containing

Ammonites (Hoplites) interruptus, Brug.
Ammonites (Hoplites) lautus (?) Sow.
Belemnites minimus, List.
Gasteropod.
Nucula pectinata, Sow.
Nuculana like *speetonensis*, Woods.
Inoceramus sp.
Cyclocyathus sp.

(The foregoing fossils were identified by Mr. E. T. Newton, F.R.S.)

It comprises a bottom junction-bed with many small pebbles and a number of phosphatic nodules, some enclosing pebbles.

Bed No. 8. At the level of 109 feet the excavation entered the upper water-bearing strata of the Lower Greensand, consisting of a sand made up of quartzite and glauconite-grains, of a sage-green colour, and containing much drift-wood. Concretionary balls of sandstone with concentric layers were also found. The water immediately rose to a height of 58 feet below the surface, and remains at that level.

Conclusion.

The conclusion arrived at is, that we have here a transported boulder of Ampthill Clay. The base of this boulder is at $82\frac{1}{2}$ feet O.D., and the bottom of the Drift at 74 feet O.D. The boulder was probably an outlier, or a portion of an outlier, situated on the Oxford Clay, at a high enough level to be ploughed into by the agent which formed the Glacial Drift, and, becoming dislodged and undercut, was carried along on this ice-foot into its present position, the line of travel being probably from the north-east. The distance from which it was moved may not have been great—perhaps not more than a mile or two—but on this point no definite opinion can be expressed. The septarian layers have a dip of 9°, and relative to the surface-levels of 4°. May this not show that the boulder, in breaking

away or in being transported, has become tilted, and this will probably limit the area of the boulder? Mr. H. B. Woodward has drawn attention to the singular absence of Jurassic outliers along the western margin of the great Lincolnshire 'cliff'; and he suggests that these huge cakes and boulders were, in some cases, dislodged from outliers which had become frozen to the base of the ice-sheet, and were then shifted to higher levels along planes produced in the ice by its movement over an irregular surface. He also observes that it is where the degrading action of the ice has been most marked, as around the Fenland border, that the large transported masses of Mesozoic strata have been most frequently noted. Among examples of such masses are the disturbed masses and transported sheets of Chalk on the Norfolk coast and at Trowse near Norwich, the huge mass at Roslyn Hole, Ely,[1] and at Catworth in Huntingdonshire. Mr. A. C. G. Cameron came upon the mass of transported Chalk, with flints and Upper-Chalk fossils, which occupied the entire area of the village of Catworth, in the Boulder-Clay, and 25 miles distant from the Chalk-formation. He also found evidence in two places of Boulder-Clay filling deep troughs at the expense of the solid rock.[2] Other well-known examples are the masses of Lincolnshire Limestone at Great Ponton, and the mass of Marlstone 200 yards across at Beacon Hill, described by Prof. Judd; while Mr. C. Fox-Strangways has observed a mass of Lincolnshire Oolite, at least 300 yards long and 100 yards broad, to the north-west of Melton Mowbray. Of special interest also is the boulder of Kimmeridge Clay found above the Lower Greensand in a well at Fodderstone Gap, near South Runcton, in Norfolk.[3] All these occur in connection with the Chalky Boulder-Clay. The large transported masses of Chalk, often with villages and forests on them, on the North German Plain, which for so long were taken as *in situ* but are now generally admitted to have been transported, may also be cited.

I am greatly indebted to Mr. H. B. Woodward, F.R.S., for much help and information, and to Mr. E. T. Newton, F.R.S., for kindly determining many of the fossils here recorded.

Postscript.

[Dr. F. L. Kitchin, M.A., F.G.S., has most kindly supplied me with the following remarks on *Ostrea discoidea* :—

The shells for which Prof. Seeley in 1862 proposed the name *Ostrea discoidea*[4] have typically a roughly-circular outline. The left valve is of evenly-convex form, and is marked by rough concentric folds and imbricating lamellæ of growth. Considerable variation accompanies an unequal duration of attachment in different individuals. In some cases, the attachment appears

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[1] H. B. Woodward, Geol. Mag. 1897, p. 495, &c.

[2] A. C. G. Cameron, Proc. Geol. Assoc. vol. xiii (1894) p. 356.

[3] Noted by Mr. C. Reid in 'The Geology of South-Western Norfolk, &c. Mem. Geol. Surv. (1893) p. 63.

[4] Ann. & Mag. Nat. Hist. ser. 3, vol. x (1862) p. 104; see also 'Jurassic Rocks of Britain' vol. v, Mem. Geol. Surv. (1895) p. 136 & fig. 62.

to be scarcely continued beyond the youthful stage, while in other individuals the margin of this valve did not become free until more than one-third of the adult dimensions were attained. The umbonal region is broad and thin, flattened or with slight incurvation. The right valve is of flat or slightly-concave form. A typical adult specimen measures 11 centimetres (or 4·4 inches) in length and breadth.

Ostrea discoidea is thinner and less massive than the large shells ascribed to *Gryphæa dilatata*, Sow., which occur in the Elsworth Rock and Ampthill Clay; it also lacks the strong marginal thickening which characterizes the last growth-stages of these. Although these *Gryphææ* are usually further distinguished by a thick and massive left umbo, sharply truncated by the surface of attachment of the youthful stage, individuals occur not infrequently which in some measure exhibit characters suggesting a passage to *Ostrea discoidea*.

Ostrea læviuscula, Sow., is distinguished from *O. discoidea* by its much flatter form, somewhat narrower outline, smoother surface, and narrow, pointed beak. —*July 1st, 1903*.]

Discussion.

Mr. H. B. Woodward observed that the thickness assigned to the Ampthill Clay at Ampthill was about 60 feet. He agreed with the Author that the transported mass had probably been removed from an outlier somewhere to the north of Biggleswade.

Mr. F. W. Harmer was much interested in the paper just read. This great boulder in the Chalky Boulder-Clay of Bedfordshire might be compared with the enormous masses of Chalk seen in the Cromer coast-section. The most important point of the paper seemed to be that it tended to show that the movement of the ice was from the north.

Mr. E. T. Newton called attention to certain of the fossils which had been found in the 67 feet of strata regarded as a portion of 'Ampthill Clay,' and considered that these fully justified the reference to that horizon. The presence of Boulder-Clay and then Gault under the great mass was good evidence of its being a transported block.

Mr. Hudleston pointed out that, if the boulder was a portion of the Ampthill Clay, we might have expected spines of *Cidaris florigemma* in such a large mass; also it was stated that fossils in that clay were usually not pyritized, whereas in the boulder there is said to be pyritization. Thus there were two reasons which rather militated against its identification as Ampthill Clay. What was the precise distance to the nearest undoubted exposure of Ampthill Clay? So far as he remembered, this clay was well shown on the Midland Railway north of the long tunnel between Bedford and Ampthill, but not at Ampthill itself. It was just possible that the boulder might have been derived from the lowest portion of the Kimmeridge Clay, and an examination of the specimens exhibited rather strengthened this view. He further commented on the remarkable thinness of the Gault, often 150 feet thick in that district, as shown in the Author's section. Had the ice ploughed away the higher portion, and left the Jurassic in the position of the oldest uppermost?

Dr. F. L. Kitchin, having complimented the Author on the lucid manner in which he had presented the facts, made a brief allusion

to one of the Ampthill-Clay oysters exhibited on the table. This was a specimen referred to Prof. Seeley's *Ostrea discoidea*, which, according to the late Thomas Roberts, is the only fossil known to be entirely restricted to the Ampthill Clay. The speaker said that while Prof. Seeley had many years ago intended to describe this form, no description, so far as he was aware, had yet been published, though the name had still remained in use. A very imperfect text-figure which had appeared in a Geological-Survey Memoir did not suffice to raise this above the level of a manuscript name.

Referring to the previous speaker's suggestion, that the mass of Jurassic clay described by the Author might possibly prove to have been derived from the lowest part of the Kimmeridge Clay, the speaker said he was not aware that *Cardioceras excavatum* had ever been known to occur in the base of the Kimmeridge Clay.

Mr. E. A. Martin asked what was the direction of the angle of dip of the septaria in the mass of Ampthill Clay, and whether it was observed to differ from the direction of the dip of similar layers in the nearest position *in situ* of the same clay. He also wished to take the opportunity of asking whether the old woodcuts, which had seen so much service in the Memoirs of the Geological Survey, could not be replaced by other and more modern methods of illustration. They were not creditable to present-day science.

Mr. Whitaker spoke of the advantage of engineers possessing a knowledge of geology, and congratulated the Society on having such work as the Author's brought before it. So far as the paper was concerned, it did not matter whether the boulder was of Ampthill or of Kimmeridge Clay; the point was that it was a true boulder.

Mr. R. S. Herries alluded to the large boulder, or series of boulders, of Lower Lias in the middle of Filey Bay, mentioned by Mr. Lamplugh in a note to his paper on the Speeton Clay in 1889. These blue clays occur mixed up with the Boulder-Clay, both in the cliff and on the foreshore, for a quarter of a mile or more, and are full of fossils belonging to the *Armatus*-zone of the Lower Lias, the nearest exposure of which is on the south side of Robin Hood's Bay, 20 miles to the north. The character of the fossils exhibited by the Author seemed to be as much Kimmeridgian as Corallian.

Prof. Watts regretted that all the various schools of glaciology were not represented at the discussion of a paper of this kind. The mechanism by which the transporting work was done was the *crux* of the problem. It was noticeable that Chalk was absent in the lea of the Wash, unless it could be identified as forming the big boulders distributed about that region. In regard to the Great Chalky Boulder-Clay, the possible agency of the Scandinavian ice-sheet must be borne in mind when seeking for an explanation of its occurrence.

The Chairman (Sir Archibald Geikie), in summing up the discussion, remarked that the paper to which they had listened

propounded two quite distinct questions for consideration. In the first place came the precise stratigraphical horizon of the strata which had been described, and the characters of the fossils which they had yielded. On these points, which were essentially palæontological, the evidence was so clear that little room was left for differences of opinion. In the second place, a fresh and interesting example had now been added to those already known of large 'cakes' of Mesozoic strata which had been transported to greater or less distances during the Ice-Age. The precise process by which this transport had been effected still remained to be satisfactorily explained. The speaker found some difficulty in conceiving that such extensive and, compared with their superficies, thin sheets of soft strata could be ploughed out and pushed forward by the ice-sheet. On the other hand, while 'cakes' of flat strata *in situ* might be frozen into shore-ice and be carried off to other parts of a region, it was not quite easy to realize the conditions in which this mode of removal could have occurred in the case of such huge masses as had now been recognized to be unquestionably erratic. In the meantime, it was important to gather all the available evidence, each addition to which might help to clear away a little of the obscurity of the problem. As a contribution towards this end, the present paper was welcomed by the Society.

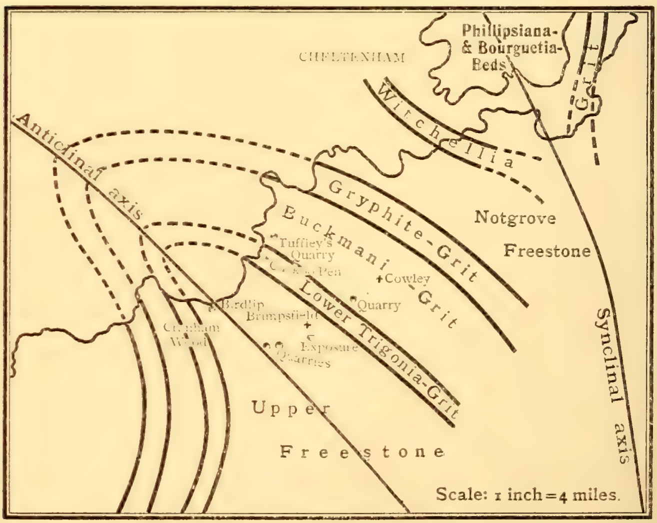
The AUTHOR said that he was very much indebted to the Fellows for the kind way in which they had received his paper. In reply to Mr. Hudleston, he suggested that the thinness of the Gault in this section might be due to its having been ploughed away by the Glacial Boulder-Clay. He hoped to be able to find out something more, in regard to the area of this boulder, in future excavations.

30. *On a* Section *at* Cowley, *near* Cheltenham, *and its* Bearing *upon the* Interpretation *of the* Bajocian Denudation. By Linsdall Richardson, Esq., F.G.S. (Read May 13th, 1903.)

To a paper communicated to this Society and published in vol. lvii (1901) p. 126 of the Quarterly Journal, Mr. S. S. Buckman, F.G.S., appended a map (pl. vi) showing the area upon which the Upper *Trigonia*-Grit was deposited. This map was corrected up to April 1900.

During a somewhat detailed investigation of the Inferior Oolite of the Cheltenham district—the results of which on the whole testify to the extreme accuracy of Mr. Buckman's work—I noticed a section exposed in a quarry about half a mile south-west of the village of Cowley, and at the north-western corner of the wood known as Cowley Wood. On Mr. Buckman's map this quarry would be represented as one-eighth of an inch due north of the *l* in Elkston. According to that author, we ought to have no

Map of the Bajocian Denudation, showing the area of the different beds upon which the Upper Trigonia-*Grit was deposited.*



'intervening beds' present here: in other words, the Upper *Trigonia*-Grit should have been seen to rest directly, and non-sequentially, upon the Upper Freestone. Thus the evidence afforded would appear (at first sight) to point to a serious flaw in the mapping of the geographical distribution of the beds upon which the Upper *Trigonia*-Grit rests. The above sketch-map, however, will

show that this is not an error in fact, but only in inference. It is possible to correct the limits of the several subdivisions upon which the deposit of the hemera *Garantianæ* was laid down, so as to agree with the facts recorded in the present paper, without interfering with those boundary-lines which are founded upon facts in Mr. Buckman's map. In other words, the present evidence rectifies portions of those limits which were drawn theoretically. If a tracing of the appended figure (p. 382) be placed upon the corresponding portion of Mr. Buckman's map, the places where the lines represented in the former differ from those in the latter will be readily ascertained.

The section exposed in Cowley Quarry is as follows, in descending order:—

Quarry near Cowley Wood.

		Thickness in Feet	inches.
Clypeus-Grit.	1. Yellowish, rubbly stone, pisolite-spherules; *Clypeus Ploti*, *Terebratula globata*, *Terebratula* sp., *Pholadomya*, *Pleurotomaria*, etc.	3	0
	2. Greyish-yellow limestone; very few fossils	1	1
Upper *Trigonia*-Grit.	3. Greyish, shelly limestone, lowest stratum bluish-grey, massive-bedded; *Terebratula globata*, *Rhynchonella hampenensis*, *Rh. angulata*, *Zeilleria Hughesi*, *Acanthothyris spinosa*, *Trigonia*, *Avicula*, *Lima*, *Ostrea*, *Holectypus*, etc.	8	8
Buckmani-Grit.	4. Greyish, arenaceous, clayey shale; *Terebratula Buckmani*, *T. crickleyensis*, *Acanthothyris* sp.	0	0 to 4
	5. Hard, grey, sandy limestone, very much bored by *Lithodomi*, less so by annelids; *Terebratula Buckmani*, *Serpula socialis*, *Trigonia formosa*, *Gervillia*, *Lima*, etc.	1	5

In 1901, when most of these notes were made, the section was considerably more interesting than it is now, for since that time the quarry has been much enlarged. This somewhat paradoxical statement is to be explained by the fact that when I first visited the section, Bed No. 4 of the above could be seen 4 inches thick at one end of the quarry, but was absent at the other. Now, however, over the greater part of the quarry, Bed No. 5 constitutes the floor.

The *Clypeus*- and Upper *Trigonia*-Grits call for no particular comments. It may be mentioned, however, that the surface of the latter has a conspicuous layer of *Ostrea* adhering to it, some of which—together with the rock to which they are attached—have been bored by *Lithodomi*. This layer of *Ostrea* upon the surface of the uppermost bed of the Upper *Trigonia*-Grit I have noticed in many sections in the Cotteswold Hills around Cheltenham: it would seem to point to another pene-contemporaneous erosion.

At the north-eastern end of Cowley-Wood Quarry the Upper *Trigonia*-Grit rests upon a grey, arenaceous, clayey shale, which

contains, somewhat abundantly, a new species of *Acanthothyris*: the one referred to by Mr. Buckman as

'an almost entirely globular species, with the spines in neat, regular rows, the first some little distance from the beak: altogether a most distinct form.'[1]

Sometimes, however, the shaly deposit is absent, and then the beds of the hemera *Garantianæ* rest upon the subjacent sandy limestone. The upper surface of this stratum is most irregular, prominences, as much as 5 inches in height, projecting above the general level of the bed. When the shaly deposit is absent this limestone is simply riddled by *Lithodomi*, but I was unable to see the degree to which it was bored when the former bed was about 3 inches thick: the face of the bed exposed when this deposit was present above it showed no signs of any borings. Thus, even in this small extent, there is a marked variation in the thickness of Bed No. 4. This is due to the planing-down process of the Bajocian Denudation, which has left it 4 inches thick at one end of the quarry, but has reduced it to nothing at the other. Moreover, it is noticeable that the south-western end of the quarry, where Bed No. 4 is absent, is in the direction of the anticlinal axis.

As regards the probable thickness and nature of the deposit belonging to the 'intervening beds' below the lowest stratum seen in Cowley-Wood Quarry, evidence may be obtained from a study of the section afforded in a quarry on the right-hand side of the road from Birdlip to Cheltenham, near the Air-Balloon Inn.

	Section in Quarry near the Air-Balloon Inn.	Thickness in Feet	inches.
Buckmani-Grit.	1. Grey, sandy, shelly stone.		
	2. Yellow, incoherent sands, with a layer of stone near the base.		
	3. Bluish and brown, clayey shale; *Terebratula Buckmani*, *T. crickleyensis*	0	6
	4. Grey, sandy stone, embedded in nodular masses in a sandy marl; thickness very variable, 4 to 10 inches	0	7
	5. Grey, sandy stone, several beds; *Acanthothyris* sp., *Modiola*	1	8
Lower *Trigonia*-Grit.	6. Slightly ironshot, rubbly, marly stone; *Gryphæa*, *Modiola*	3	2
	7. Earthy layer; *Rhynchonella* sp., a much-crushed *Aulacothyris Meriani*	0	4
Upper Freestone.	8. Whitish, oolitic freestone; (visible)	9	6

Bed No. 5 of the Cowley-Wood section is doubless Bed No. 5 of the above record, so that at the former locality a maximum thickness of $5\frac{1}{2}$ feet may be expected for the 'intervening beds': Bed No. 4 of the above section being wanting at Cowley.

The question now arises as to the extent of the area of the Lower *Trigonia*-Grit immediately below the Upper *Trigonia*-Grit.

[1] Quart. Journ. Geol. Soc. vol. li (1895) p. 447.

This extent is, I think, very limited. There is only one section, namely, at Cuckoo-Pen Quarry, where these two subdivisions are seen in juxtaposition; and there the Lower *Trigonia*-Grit is only 3 feet 2 inches thick. The reasons why a very limited area might be anticipated are as follows. At the close of the hemera *bradfordensis*, and consequently of the Aalenian Age, the deposits were thrown into a series of flexures, with the result that at Birdlip there was an anticlinal axis. Denudation of the Birdlip anticline proceeded for a considerable time, and continued while the Harford Sands, Snowshill Clay, and Lower *Trigonia*-Grit (*pars*) were being deposited farther north. At Leckhampton Hill the Snowshill Clay is seen to have overlapped the Harford Sands, and to rest non-sequentially upon the Upper Freestone. At the same locality, but a little farther to the west, the Snowshill Clay is absent, and the Lower *Trigonia*-Grit rests directly upon the Upper Freestone: the lower portion of the Lower *Trigonia*-Grit being markedly conglomeratic. It is now necessary to look for a higher horizon in the Lower *Trigonia*-Grit upon which further to demonstrate this overlap. At Charlton Common the *Aulacothyris Meriani*-Bed occurs 16 inches above the base of the subdivision; at Tuffley's Quarry it has been fixed at 8 inches above the base: while at Cuckoo Pen it has not been observed, although a diligent search has been made. At all events, there is a noticeable decrease in the thickness of the deposits of the hemera *Discitæ*; and this being due to overlap, it follows that the reduction is attributable to the Upper Freestone not having been sufficiently submerged to allow of the accumulation of sediment. At Cuckoo Pen, however, the Lower *Trigonia*-Grit has been denuded during the Bajocian Denudation also. At Tuffley's Quarry 10 feet 2 inches of deposit separate the Upper *Trigonia*-Grit from the Upper Freestone: at Cuckoo Pen the thickness of the intervening deposit is but 3 feet 2 inches. Tuffley's Quarry is distant about 6 furlongs from that at Cuckoo Pen.

The causes producing the Bajocian Denudation appear to have been forces so acting as to effect a repetition of flexures along old lines of weakness, and thus in the Birdlip area we may again locate an anticline. This time, however, the elevation was much greater: it may be measured by the fact that the Upper *Trigonia*-Grit rests upon the Upper Freestone; indeed, the level of the Aalenian Denudation was passed by the Bajocian. If so much deposit was removed in the short distance between Tuffley's and Cuckoo-Pen Quarries, it would appear that so thin an accumulation as the Lower *Trigonia*-Grit—reduced in thickness between Leckhampton and Birdlip, owing to the fact that it overlaps the Upper Freestone, as already demonstrated—would soon be denuded; in other words, the extent, from the place where the Upper *Trigonia*-Grit rests upon the basement-bed of the *Buckmani*-Grit to where it rests upon the highest part of the Upper Freestone, would not be very great. Indeed, it is improbable that it exceeds half a mile;

it would be nearer to the quarter. This opinion, concerning the limited area of the Lower *Trigonia*-Grit upon which the Upper *Trigonia*-Grit rests, is supported by the fact that at Cowley-Wood Quarry the latter deposit rests upon what appears to be the clay-bed of the *Buckmani*-Grit (eastern end of the quarry); while just over 6 furlongs to the south-west by south, and near Park House, Brimpsfield, we see the *Clypeus*- and Upper *Trigonia*-Grits above the Upper Freestone, the surface of which is slightly bored by *Lithodomi* and annelids. Similar phenomena would seem to obtain south of the Birdlip anticline, in the neighbourhood of Cranham Woods. At Dunley Quarry, as shown by Mr. Buckman, the Upper *Trigonia*-Grit rests upon the *Buckmani*-Grit, and is separated by a considerable thickness of deposit from the base of the latter. Nevertheless, about 650 yards to the north-east the 'intervening beds' are absent: the Upper *Trigonia*-Grit rests directly upon the Upper Freestone.

As pointed out by Mr. Buckman,[1] *Terebratula fimbria* is not uncommon in Cranham-Woods Quarry at $3\frac{1}{2}$ feet, 4 feet, and again at $4\frac{1}{2}$ feet, below the top of the Upper Freestone. The inference which he draws is that the maximum of the Bajocian Denudation was attained in this quarry, for 6 furlongs farther north $4\frac{1}{2}$ feet of Upper Freestone are visible, and yet there is no bed with *Terebratula fimbria*. In connection with the exact location of this anticlinal axis, the three following sections may be of interest. The first is situated about nine-tenths of a mile south-west by west of Brimpsfield Church.

SECTION IN QUARRY NEAR BRIMPSFIELD.

(Nine-tenths of a mile south-west by west of the Church.)

		Thickness in Feet	inches.
CLYPEUS-GRIT.	1. Whitish, oolitic limestone, passing down into a brownish rock in which *Terebratula globata* is abundant; about ...	6	0
UPPER TRIGONIA-GRIT.	2. Grey, shelly limestone, surface of top-bed covered with *Ostrea*; *Terebratula globata*, *Rhynchonella subtetrahedra*, *Rh. angulata*, *Rh. hampenensis*, *Acanthothyris spinosa*, *Avicula*, *Lima*, *Trigonia*, *Ostrea*, etc.	6	6
	3. Brownish earthy deposit, with pebbles occasionally	0	2
UPPER FREESTONE.	4. Whitish oolitic freestone, top-bed bored; *Terebratula fimbria* in stratum 2 feet 6 inches down; (visible)	4	0

This section is, I consider, one of the best of the Upper *Trigonia*-Grit in the Cotteswolds. It is especially noticeable, on account of the occurrence, somewhat abundantly, of *Acanthothyris spinosa* and *Zeilleria Hughesi*. The exact horizons at which *Terebratula fimbria* was noticed were at 30, 35, and 39 inches down. A fifth of a

[1] Quart. Journ. Geol. Soc. vol. li (1895) p. 407.

mile to the north-east by north is another quarry, yielding the following section:—

QUARRY NEAR BRIMPSFIELD.

(Seven-tenths of a mile south-west by west of the Church.)

		Thickness in Feet	inches.
UPPER *TRIGONIA*-GRIT.	1. Greyish, shelly limestone; *Terebratula globata, Zeilleria Hughesi, Rhynchonella angulata, Acanthothyris spinosa, Trigonia, Avicula, Ctenostreon*; *Oppelia subcostata* 19 inches above the Upper Freestone	8	0
	2. Brownish earthy layer, with pebbles of Upper Freestone	0	4
UPPER FREESTONE.	3. Hard, whitish, oolitic freestone, top-bed bored; *Terebratula fimbria* noticed 2 feet 8 inches down; (visible)	3	3

The horizon at which *Terebratula fimbria* occurs in this section appears to be about the same as in the previous one. Provisionally, we may conclude that the anticlinal axis runs south of these quarries. The reduction to the south-east from Dunley to Brimpsfield is what would be expected, as in that direction the Upper Freestone must become thinner until the Upper *Trigonia*-Grit rests upon the Oolite-Marl.

The third section may be constructed by piecing together the evidence afforded by the quarry on the south side of the road from Birdlip to Prinknash, and by the quarried face of the hill immediately to the north thereof, on the other side of the road:—

QUARRY SOUTH OF THE BIRDLIP AND PRINKNASH ROAD, IN CRANHAM WOOD.

		Thickness in Feet	inches.
UPPER *TRIGONIA*-GRIT.	1. Grey, shelly rock; *Rhynchonella hampenensis, Rh. angulata, Rh. subtetrahedra, Terebratula globata, Aulacothyris carinata, Trigonia*, etc.	4	0
UPPER FREESTONE.	2. Yellowish-white freestone, top-bed slightly bored by annelids; a single specimen of *Terebratula fimbria* occurs 3½ feet down, while at 5 feet 10 inches this shell is somewhat plentiful, and is associated with *Lucina, Trigonia*, and numerous specimens of *Nerinæa*	7	10

Crossing to the other side of the road, we have in the uppermost excavation:—

		Thickness in Feet	inches.
UPPER *TRIGONIA*-GRIT.	1. Rubble with *Terebratula globata*, etc.		
UPPER FREESTONE.	2. Whitish freestone, top-bed bored; *Terebratula fimbria* 3 feet 7 inches down	3	8

The section below again shows :—

		Thickness in Feet	inches.
UPPER FREESTONE.	2. Yellowish-white freestone ; about	7	0
OOLITE-MARL.	3. Yellowish-white marl crowded with *Terebratula fimbria,* var., and less so with *T. submaxillata* and *Rhynchonella subobsoleta* ; (visible)	1	2

The foregoing record shows a thickness of 10 feet 8 inches for the Upper Freestone. It is in the uppermost 2 inches of the Oolite-Marl that *Terebratula fimbria* occurs the most abundantly, and the majority of the specimens are very coarsely fimbriated.

The evidence afforded from the horizons at which *Terebratula fimbria* has been noticed in the particular quarries in which the Upper Freestone is exposed, and mentioned in this paper, would indicate that the maximum upheaval of the strata in the Birdlip area is as shown in the sketch-map (p. 382). As regards the geographical extent of the subdivisions upon which the Upper *Trigonia*-Grit rests to the south-west of this anticlinal axis I give it on the authority of Mr. S. S. Buckman.[1]

That the forces which caused the flexuring of the strata, and the consequent erosion known as the 'Bajocian Denudation,' affected the Liassic rocks also, is obvious. Consequently, the exact location of the anticlines and synclines of the Inferior-Oolite rocks in the Cotteswold Hills, where sections are numerous, may afford some important working hypotheses for unravelling the structure of the Vale of Gloucester, where excavations are few.

DISCUSSION.

The Rev. H. H. WINWOOD said that the Author was doing a good work in the Cotteswold district, and evidently working on Mr. Buckman's lines, adopting both his views and nomenclature. The many details given in the paper required careful reading and consideration before an opinion of any value could be formed.

Mr. H. B. WOODWARD looked upon the Cotteswold fossiliferous 'grits' as representing local conditions of the sea-bed. The remarkable point was the extension of the Upper *Trigonia*-Grit over the other beds. The anticline, if drawn to scale, was not very conspicuous.

Mr. R. S. HERRIES thought that it was impossible for anyone not knowing the ground in detail, to follow or accept inferences of denudation founded on the thinning-out in a single quarry of a bed 4 inches thick ; but the evidence was sufficiently convincing when pointed out on the spot by Mr. Buckman.

Prof. GROOM thought that the interest attached to an unconformity was not always in proportion to the magnitude of the

[1] Quart. Journ. Geol. Soc. vol. lvii (1901) pl. vi.

break. The small unconformity investigated by Mr. Buckman and the Author was of importance in several ways. It might help to explain the unexpected absence of certain zone-fossils from beds elsewhere; it threw light upon the variations in thickness of an apparently conformable series of beds; and it presented a case of 'contemporaneous erosion' which showed all the essential features of a true unconformity. Doubtless many other, hitherto undiscovered, examples of the same kind existed. A study of these in the strata of a folded mountain-chain might be expected to throw much light upon the gradual building-up of the chain. In connection with the repetition of a movement at a subsequent date, to which the Author had made allusion, attention might be drawn to the parallelism of certain of the movements on the two sides of the Severn Valley: thus the synclinal axis drawn by Mr. Buckman between Painswick and Stroud appeared to coincide with that between the Woolhope and Ledbury districts. It was to be hoped that the Author and others would continue their studies in the district, and would extend them to a consideration of the folds traversing the strata at the surface.

31. *The* Rhætic *and* Lower Lias *of* Sedbury Cliff, *near* Chepstow (Monmouthshire). By Linsdall Richardson, Esq., F.G.S. (Read June 24th, 1903.)

[Plate XXIV—Vertical Section.]

On the opposite side of the Severn to Aust Cliff, and 2 miles north-north-west of that section, there is a corresponding elevation known as Beachley, Aunard's, or Sedbury Cliff. Chepstow lies to the west-north-west, and in a direct line is distant about $1\frac{1}{4}$ miles, but by road about $2\frac{1}{4}$ miles. I have distinguished the cliff-section as that of Sedbury, since Sedbury Park, the country-seat of Sir William Marling, Bart.—to whom, and to Mr. S. S. Marling, I am indebted for permission to examine the cliff and for kind assistance—is situated on the Rhætic and Liassic outlier.

The literature relating to the section is not voluminous. In that which has come under my notice I find it incidentally mentioned in several papers,[1] and briefly noticed in two other communications. The earliest account is that given by the Rev. P. B. Brodie, but it is based upon information supplied by Mr. Higgins.[2] This account may be summarized as follows. There is a development of true 'Insect-Limestone' above the 'Landscape-Stone,' and although they are separated one from the other by 4 feet of shale at the eastern end of the section, at the western they thin out and blend as at Aust. The 'Landscape-Stone' contains a great variety of insect-remains, some of which are tolerably perfect. The '*Cypris*- and Plant-Bed' is seen in its proper position, and in every case possesses a true 'Landscape' character. Sir W. V. Guise observed that this section closely resembled the exposure at Aust, yet presented differences which gave it a certain speciality:—

'The exposure of Lower Lias is considerably greater, and abounds in such characteristic fossils of the formation as *Lima gigantea*, *Ammonites planorbis*, and its thicker variety *A. Johnstoni*, *Ostrea liassica*, etc. The Rhætic Beds resemble very closely those at Aust—the "Bone-Bed" is but feebly represented—*Avicula contorta* is present occasionally.'[3]

It will be seen, then, that very little is known concerning the sequence of the component beds of the Rhætic Series at this locality: hence the origin of the present paper. Unfortunately the cliff is very awkward to examine, and even when an apparently-suitable place for the investigation of the Rhætic Beds has been discovered, these deposits are found to be hidden under a considerable accumulation of slipped rock. The dip being riverwards,

[1] H. Wills, Trans. Clifton Coll. Sci. Soc. pt. iii (1872) pp. 49, 55; Brit. Assoc. (Bristol, 1898) Handbook of Excursions, 'Aust & Over Court'; S. S. Buckman, Proc. Cotteswold Nat. F. C. vol. xiii (1901) p. 278.

[2] 'A History of the Fossil Insects in the Secondary Rocks of England' 1845, pp. 83–85.

[3] Proc. Cotteswold Nat. F. C. vol. vi (1877) pp. 270–71.

slips on a large scale are of frequent occurrence; and the work of destruction is hastened by a number of springs, which have also caused large deposits of travertine to be formed, and masses of this are seen on the beach.

The chief portion of the cliff-section now to be described has a direction north-east and south-west; the dip of the beds is south-south-easterly, at an angle which does not exceed 3°.

The Upper Keuper Marls constitute the base of the section, and are exposed for a thickness of about $66\frac{1}{4}$ feet. This thickness includes 56 feet of red marl, and $10\frac{1}{4}$ feet of 'Tea-green Marls.' The term 'Tea-green Marls' for these $10\frac{1}{4}$ feet of deposit is quite a misnomer here, for the predominating tint is yellow. They may be thus described:—

	Thickness in	
	Feet	*inches.*
(*a*) Yellowish-green, somewhat soft marl	2	0
(*b*) Hard band of marlstone	0	7 to 11
(*c*) Marl similar to *a*, but with hard nodular masses	7	6

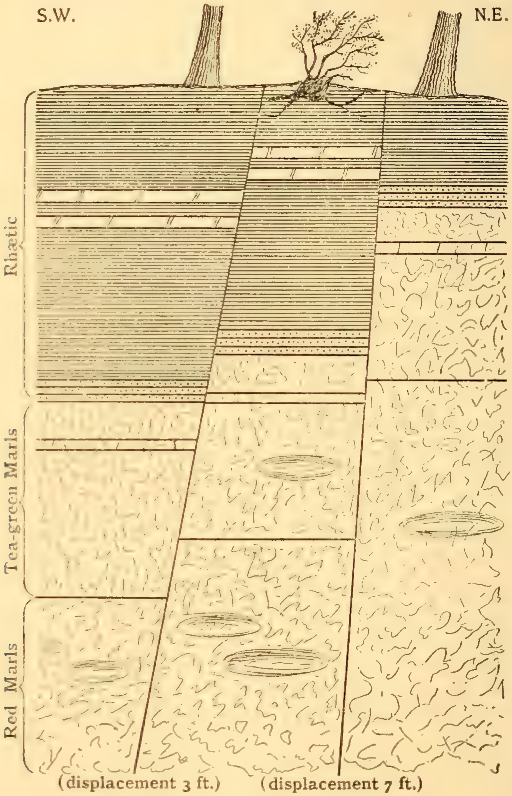
The 'Tea-green Marls,' together with the greater number of the component deposits of the Lower Rhætic stage, are best examined at the step-fault shown in the accompanying figure (p. 392), and distant about 30 yards north-east from the place where Offa's Dyke terminates on the cliff.

Resting upon the 'Tea-green Marls' is the Bone-Bed, but here (as the late Edward Wilson showed was also the case at Pylle Hill, Bristol) the line of junction between the two stages—the Upper Keuper and Lower Rhætic—is sharply defined, palæontologically and lithologically. On the other hand, however, the 'Tea-green Marls' graduate downward imperceptibly into the Red Marls. The Bone-Bed usually occurs in the form of one or more layers of light-grey, micaceous sandstone; but this development is sometimes replaced by an interesting conglomerate, in all respects similar to that so well known at Aust Cliff. The latter occurrence, however, is the exception rather than the rule. One subangular mass of marl had a diameter of 8 inches. In the conglomerate vertebrate remains are well-preserved, but often crumble away when an attempt is made at extraction. No less than fifteen specimens of *Sargodon tomicus* were observed in a piece of the Bone-Bed with a superficial extent of one square inch, but unfortunately shivered while the piece was being detached from the larger mass. To Dr. A. Smith Woodward, F.R.S., I am indebted for kindly examining a few of the fish-remains; but it will be noticed that in the list of organic remains from Bed 15 appended to Pl. XXIV[1] no mention is made of the

[1] In order to facilitate the correlation of this section with those in North-West Gloucestershire, I have employed numbers for the various beds corresponding with those given in my paper on 'The Rhætic Rocks of North-West Gloucestershire' Proc. Cotteswold Nat. F. C. vol. xiv (1903) pp. 127–74.

teeth of *Ceratodus*. This is remarkable, considering the proximity to Aust, where so many have been found. Their non-record, moreover, is not due to inadequate investigation of the bed, for many hours' attention was bestowed upon this stratum alone. The sandstone-layers considered as equivalent to Beds 13 & 14 of the North-West Gloucestershire sections, and which alternate with shaly deposits, are conspicuously ripple-marked, and often covered

Step-fault, 30 yards north-east of Offa's Dyke. (See p. 391.)



Vertical & Horizontal Scales:— 10 feet = 1 inch.

with obscure markings similar to those described to this Society by Strickland on November 30th, 1842.[1] In the Bone-Bed proper (No. 15) casts of lamellibranchs occur, resembling *Schizodus* and a broad form of *Modiola minima*. Intervening between the beds numbered 13 & 14, and 7, is a deposit of black shale 7 feet thick. At 6 inches above the former deposit are 14 inches of black shale, thinly laminated and very firm; and this stratum, projecting from the cliff, constitutes a prominent feature. The succeeding 5 feet

[1] Proc. Geol. Soc. vol. iv, pp. 16–18.

4 inches of black shale are replete with the ordinary Lower Rhætic fossils at certain horizons. Bed 7 is a useful datum-level upon which to correlate sections, and is separated from a similar limestone-bed by 6 inches of fossiliferous shale.

Reference to Edward Wilson's record of the Pylle-Hill section,[1] and that given by Mr. W. H. Wickes of a section at Redland (New Clifton), Bristol,[2] will show how closely the Sedbury-Cliff section at this horizon resembles them. An interesting record is that of the teeth of *Acrodus minimus* from Bed 7—a somewhat high horizon for this species. The specimens of *Pecten valoniensis* are well-preserved in Bed 7, which exhibits two lithological varieties. The one is a hard, slightly pyritic, and regularly-bedded rock; the other, extremely hard, blackish-blue, and occurring in somewhat lenticular masses. In that portion of the cliff which includes the step-fault, the shales immediately above 5*b* have suffered much from weathering and their nearness to the surface. Doubtless—as investigation at other points in the cliff shows—the lower portion of the immediately-superincumbent shales was once black, but is now brownish-black and greenish-grey with whitish streaks, owing to atmospheric influences. Bed 5*a* is only grouped provisionally with the Lower Rhætic, and, although *Avicula contorta* has not been recorded therefrom as yet, I have little doubt that if it had been possible to investigate the deposit more thoroughly, that lamellibranch would have been found.

Brodie's '*Cypris*- & Plant-Bed,' or the *Estheria*-Bed, is another good datum-level. Lithologically, it resembles its equivalent in the North-West Gloucestershire sections, of which I have given details elsewhere.[3] In places it presents the 'Landscape' phenomenon noticed by Brodie; but the *Estheriæ* are very rare, and I have not recorded *Naiaditæ*. Concerning this and the succeeding beds belonging to the Rhætic Series, and also the one classed as the basement-bed of the Lias, Brodie wrote:—

> 'At this cliff as well as at Aust, and on Bedminster Down, the "*Cypris*- and Plant-Bed" is seen in its proper position, and in every case possesses a true "Landscape" character. This, in addition to its position and fossils, serves to identify it with the same bed at Wainlode, Westbury, etc., etc., and also with the "firestone" of Warwickshire. Thus far the resemblance is clear, but the intervening stratum between the "Insect-Limestone" and "*Cypris*-Bed" is evidently wanting in other places. The "Landscape-Stone," from its peculiar mineralogical aspects, is in all probability more closely connected with the "*Cypris*- and Plant-Bed," than with the "Insect-Limestone," with which it only blends when the clays which separate the two are absent. The "Landscape-Stone" encloses many *Cypris* and fragments of minute Plants, and a few small Fish.'[4]

In some parts of the cliff the *Estheria*-Bed occurs in nodular masses and exhibits arborescent markings, but it may be observed to pass

[1] Quart. Journ. Geol. Soc. vol. xlvii (1891) table facing p. 546.
[2] Proc. Bristol Nat. Soc. vol. ix (1899) pl. i, facing p. 100.
[3] *Ibid.* vol. x (1901) pp. 72–76.
[4] 'Fossil Insects' 1845, p. 84.

laterally into a greenish fine-grained rock without these markings; also into a cream-coloured, somewhat laminated rock.

Immediately above the *Estheria*-Bed, or separated therefrom by a thin clayey deposit, is a gritty band from $\frac{1}{4}$ to 2 inches thick. In one part of the section (more towards the north-east) the *Estheria*-Bed is separated from the next hard stratum by 2 feet of deposit, but in another the intervening deposit is as much as 3 feet 4 inches thick. Where the former thickness was obtained at a horizon 1 foot above the *Estheria*-Bed, ostracods were most abundant—their exact position being indicated by a yellowish streak. Prof. T. R. Jones, F.R.S., kindly examined these, and reported that they included *Darwinula liassica* and varieties. I observed ostracods at the same horizon—at least, 1 foot below the Cotham Marble—in the Lilliput cutting on the South Wales Direct Line near Chipping Sodbury. The shales whence the ostracods are procurable are Bed M of Wilson. I was unable to see the Cotham Marble exhibiting arborescent markings. That it is present in such a form, however, is shown by the information supplied to Brodie by Higgins.

My investigations showed that the basement-bed of the Lower Lias is conglomeratic, and that below—to which the conglomerate adheres—is sometimes present a limestone having a peculiar flinty fracture. This thin layer of conglomerate indicates a non-sequence. In places the conglomerate rests upon this limestone (Cotham Marble), and in others upon the shales (Bed 2). Fallen masses on the beach also showed that the conglomerate, in some places was attached to a limestone-bed, in others that this limestone-stratum was absent (several masses exhibited thin remnants of limestone, bored, just below the conglomerate); and also that when this Cotham Marble was absent the conglomerate was attached to the next bed in ascending order—sometimes a fissile limestone, and sometimes a stratum crowded with *Ostrea*.

It would appear, according to the classification which I followed in North-West Gloucestershire, and also in the case of a section at Woodnorton, near Evesham,[1] that the fissile bed and the conglomerate (the latter on about the horizon of the *Pseudomonotis*-Bed of that locality) were classed with the Upper Rhætic; indeed, it is highly probable that the band of *Ostrea* is the equivalent of the 'Bottom-Bed' of those sections, and that the fissile limestone is the equivalent of the shales (*pars*) intervening between the 'Bottom-Bed' and the *Pseudomonotis*-Bed of the Wainlode and Garden-Cliff sections. In connection with the conglomerate-bed, it may be noted that the remanié bed of Lassington occurs 11 feet 4 inches below deposits known to yield *Psiloceras planorbis*.[2]

The Lower Liassic beds succeed, and present the faunal and lithological characters so well known in the West of England.

[1] Geol. Mag. 1903, p. 82.

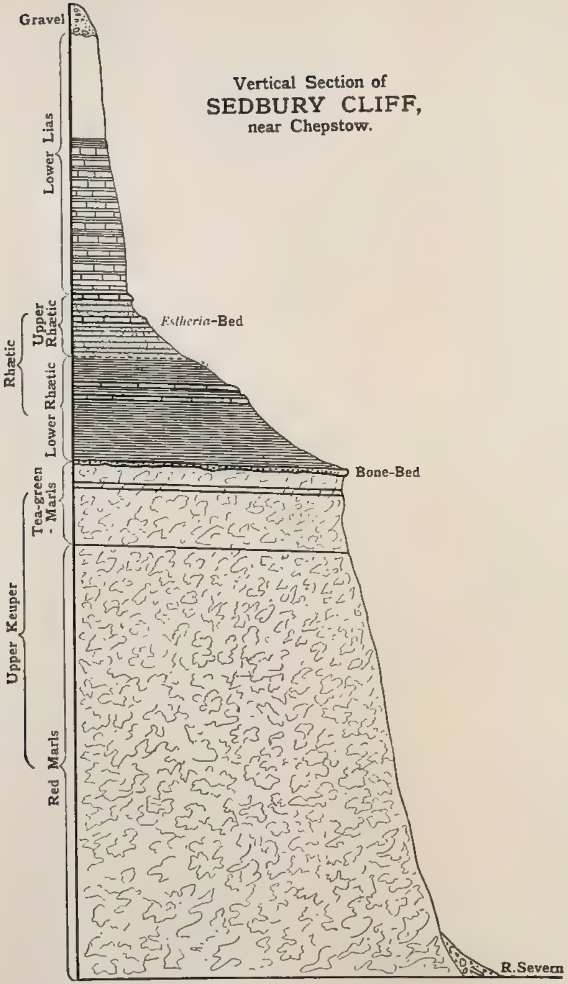
[2] 'The Jurassic Rocks of Britain' vol. iii, Mem. Geol. Surv. (1893) p. 141.

BURY CLIFF, NEAR CHEPSTOW.

	Feet	inches.	
......	24	0	*Ammonites (Psiloceras) Johnstoni, Lima gigantea.*
......	2	7	*Ammonites (Psiloceras) planorbis* (teeming in the top bed), *Am. (Psil.) Johnstoni, Lima gigantea, Modiola minima, Cardinia, Anomia.*
....	0	11	Fishes (scales), *Anomia, Pseudodiadema.*
....	1	4	*Ammonites (Psiloceras) planorbis, Modiola minima, Lima gigantea, L. pectinoides.*
nds.	4	0	Fishes (scales), *Ostrea liassica, Lima pectinoides, Avicula fallax,*[2] *Anomia, Pseudodiadema.*
.....	0	4	*Ostrea liassica, Lima Hermanni, L. pectinoides, L. valoniensis, Anomia, Pectens* of *calvus* & *textorius*-types, *Pseudodiadema* (spines).
.....	1	0	*Ostrea liassica, Modiola minima, Avicula fallax.*
.....	1	8	*Pleuromya crowcombeia, Ostrea liassica, Modiola minima, Avicula fallax, Protocardium rhæticum, Unicardium cardioides.*
.....	1	1	*Pleuromya crowcombeia, Ostrea liassica, Modiola minima, Lima valoniensis, Avicula cygnipes, Phasianella (?).*
iam	0	0 to 2	Fishes (scales) and shell-fragments *(Ostrea ?).*
to	2	0	*Darwinula liassica* and varieties.
eral bed, psit, to	0	8	*Estheria minuta* var. *Brodieana, Schizodus (?), Pleurophorus,* fishes (scales ?).
....	3	5	*Myophoria, Pecten,* and shell-fragments.
....	2	4	*Pecten valoniensis, Schizodus Ewaldi, Myophoria Emmerichi, Protocardium rhæticum.*
vn ;	0	5	*Pecten valoniensis, Gyrolepis Alberti.*
....	0	6	*Schizodus* and shell-fragments.
tic ; ice ;	0	6	*Acrodus minimus, Saurichthys acuminatus, Gyrolepis Alberti, Hybodus minor, Pecten valoniensis, Avicula contorta, Protocardium rhæticum, Modiola minima, Schizodus Ewaldi,* coprolites, and an ichthyodorulite.
sils	5	4	*Schizodus Ewaldi, Modiola minima, Pleurophorus elongatus, Pl. angulatus, Protocardium rhæticum.*
....	1	2	
....	0	6	
ne, ...	0	8	*Acrodus minimus, Gyrolepis Alberti* (scales & teeth ?), *Saurichthys acuminatus,* and small coprolites.
ht- een us, ...	0	4	*Gyrolepis Alberti* (scales and teeth ?), *Sargodon tomicus, Saurichthys acuminatus, Hybodus cloacinus, H. minor, Acrodus minimus, Nemacanthus* (spines), *Modiola, Schizodus (?),* Labyrinthodont-tooth, skin of *Hybodus,* coprolites, fish-vertebræ, piece of wood.
ith	10	3	
rel-	56	0	

ken blocks on the shore.

e Lower Lias were determined by Mr. Arthur Vaughan, F.G.S.



Vertical Scale:- 20 feet = 1 inch

Section at Sedbury Cliff, near Chepstow.

			Feet	inches.	
Lower Lias.		Shales & limestone-bands[1]	24	0	*Ammonites (Psiloceras) Johnstoni, Lima gigantea.*
		Limestones, with thick deposits of shale	2	7	*Ammonites (Psiloceras) planorbis* (teeming in the top bed), *Am. (Psil.) Johnstoni, Lima gigantea, Modiola minima, Cardinia, Anomia.*
		Shales	0	11	Fishes (scales), *Anomia, Pseudodiadema.*
		Limestone, with band of shale	1	4	*Ammonites (Psiloceras) planorbis, Modiola minima, Lima gigantea, L. pectinoides.*
		Shales, very fissile, with two thin limestone-bands.	4	0	Fishes (scales), *Ostrea liassica, Lima pectinoides, Avicula fallax,*[2] *Anomia, Pseudodiadema.*
		Limestone	0	4	*Ostrea liassica, Lima Hermanni, L. pectinoides, L. valoniensis, Anomia, Pectens* of *calvus* & *textorius*-types, *Pseudodiadema* (spines).
		Shale, with a limestone-band	1	0	*Ostrea liassica, Modiola minima, Avicula fallax.*
		Shales, with limestone-bands	1	8	*Pleuromya crowcombeia, Ostrea liassica, Modiola minima, Avicula fallax, Protocardium rhæticum, Unicardium cardioides.*
		Limestones, with shale-partings	1	1	*Pleuromya crowcombeia, Ostrea liassica, Modiola minima, Lima valoniensis, Avicula cygnipes, Phasianella (?).*
		Conglomerate, composed of fragments of Cotham Marble	0	0 to 2	Fishes (scales) and shell-fragments *(Ostrea ?).*
Upper Rhætic.	2.	Shales, greenish-grey, thinly laminated; 2 to 3½ feet	2	0	*Darwinula liassica* and varieties.
	3.	*Estheria*-Bed or '*Cypris*-Bed.' Presents several lithological modifications. Resting upon this bed, or separated therefrom by a thin clayey deposit, is a sandy layer ¼ to 2 inches thick; 4 to 12 inches	0	8	*Estheria minuta* var. *Brodieana, Schizodus (?), Pleurophorus,* fishes (scales ?).
	4.	Shales, greenish-grey, imperfectly laminated	3	5	*Myophoria, Pecten,* and shell-fragments.
Lower Rhætic.	5 a.	Shales, black, laminated	2	4	*Pecten valoniensis, Schizodus Ewaldi, Myophoria Emmerichi, Protocardium rhæticum.*
	5 b.	Limestone, hard, blackish-blue, weathers brown; 3 to 8 inches	0	5	*Pecten valoniensis, Gyrolepis Alberti.*
	6.	Shales, black, earthy; full of shell-débris	0	6	*Schizodus* and shell-fragments.
	7.	Limestone, hard, bluish-black, slightly pyritic; layer of fibrous calcite on the under-surface; weathers brown; 4 to 8 inches	0	6	*Acrodus minimus, Saurichthys acuminatus, Gyrolepis Alberti, Hybodus minor, Pecten valoniensis, Avicula contorta, Protocardium rhæticum, Modiola minima, Schizodus Ewaldi,* coprolites, and an ichthyodorulite.
	8. 9. 10.	Shales, black, sandy streaks, selenitic. Fossils very abundant at certain horizons	5	4	*Schizodus Ewaldi, Modiola minima, Pleurophorus elongatus, Pl. angulatus, Protocardium rhæticum.*
	11.	Shales, black, firm, thinly laminated	1	2	
	12.	Shales, black, earthy	0	6	
	13. 14.	Sandstone-layers & shale alternating. Sandstone, calcareous, micaceous, small quartz-pebbles	0	8	*Acrodus minimus, Gyrolepis Alberti* (scales & teeth ?), *Saurichthys acuminatus,* and small coprolites.
	15.	Sandstone (Bone-bed); coarse, calcareous, light-grey sandstone, with masses of 'Tea-green Marl'; in places non-conglomeratic. Micaceous, quartz-pebbles	0	4	*Gyrolepis Alberti* (scales and teeth ?), *Sargodon tomicus, Saurichthys acuminatus, Hybodus cloacinus, H. minor, Acrodus minimus, Nemacanthus* (spines), *Modiola, Schizodus (?),* Labyrinthodont-tooth, skin of *Hybodus,* coprolites, fish-vertebræ, piece of wood.
Upper Keuper.	I.	'Tea-green Marls.' Yellowish-green marls, with a hard band of marlstone	10	3	
	II.	Red Marls, angular fracture; bluish-grey & yellowish zones & blotches	56	0	

[1] These could only be examined in broken blocks on the shore.
[2] This and several other fossils from the Lower Lias were determined by Mr. Arthur Vaughan, F.G.S.

EXPLANATION OF PLATE XXIV.

Vertical section of Sedbury Cliff, on the scale of 20 feet to the inch.

Discussion.

Mr. Hudleston drew attention to Bed 15 of the Lower Rhætic in the Author's section. It was important to notice that in this area the sandstone (Bone-Bed) contained masses of 'Tea-green Marl.' Since it was held by some that these 'Tea-green Marls' actually formed a portion of the Rhætic, the inclusion of derived masses of the underlying bed helped to corroborate the late Edward Wilson's view, which entirely dissociated these 'marls' from the Rhætic Series. Recently a paper had been read before the Society, wherein the author included the green marls,[1] as a matter of course, in the Rhætic. Owing to criticisms made at the time, he (the speaker) had been assured by Bristol geologists that additional evidence was forthcoming in that district in conformity with Edward Wilson's views, which he desired to emphasize.

Mr. H. B. Woodward remarked that the previous speaker had raised a controversial matter that had been pretty well thrashed-out. The Tea-green Marls were no doubt passage-beds between the Keuper and the Rhætic. If one went a little farther south, one would find a bone-bed in these green marls, and in going westward to Bridgend, in South Wales, one would find red marls on the horizon of the Upper Rhætic, as noted by Tawney, and lately confirmed by the officers of the Geological Survey. Red marls also occur on a similar horizon in Antrim, as observed by the late Ralph Tate. He agreed with the Author in regard to the conglomerate at the base of the Lias. In the Bristol district and northward there was evidence of erosion of the White Lias. He regarded the *Estheria*-Bed of Westbury-on-Severn as probably representing the Cotham Marble: it contained arborescent markings.

Mr. Whitaker said that, so far as the Bristol area was concerned, he agreed with the late Edward Wilson that the Tea-green Marls were perfectly distinct from the Rhætic, and belonged to the Keuper. He cited in confirmation Hébert's opinion as to the section at Aust Cliff, and remarked that he could not sufficiently deprecate the differentiation of beds by colour alone.

[1] [A. J. Jukes-Browne, Quart. Journ. Geol. Soc. vol. lviii (1902) pp. 281–82.]

32. *The* Lowest Beds *of the* Lower Lias *at* Sedbury Cliff. By Arthur Vaughan, Esq., B.A., B.Sc., F.G.S. (Read June 24th, 1903.)

The two chief points of interest in the Lower Lias of Sedbury Cliff, which I examined in company with Mr. L. Richardson, are, firstly, the relation of the basal conglomerate to the Cotham Marble and White Lias of neighbouring districts; and, secondly, the examination of the faunal sequence, with a view to testing the absolute value of ammonite-zones.

1. The Conglomerate.

This is composed of fragments of a very compact, lithographic, argillaceous limestone, which exhibits well-marked conchoidal fracture. The large fragments are invariably tabular and lie horizontally, their vertical dimension being small compared with their horizontal extent; all of them show internal, horizontal bands of colour which may undoubtedly be considered to have existed in the original rock-layer from which the fragments were broken. The smaller fragments lie in all directions, and many of them are rounded; they almost invariably exhibit an outer, more deeply stained shell, the colour of which shades off inward quite uniformly and imperceptibly. There can be little doubt that this staining has been produced subsequently to the breaking and rolling of the fragments, and, most probably, subsequently to their cementation into a conglomerate.

That the fragments of the conglomerate once formed part of a layer exactly similar to the true Cotham Marble of the Bristol and Sodbury areas, is almost without question, since they agree absolutely in lithological characters with specimens of that rock, though I have noticed no fragments which show the peculiar arborescent markings. It is, however, important to notice that the arborescent marking, though peculiar, does not form an essential character of the Cotham-Marble layer, being very commonly absent[1]; whereas some form of undulating, horizontal banding, especially near the base of the layer, is almost invariable.

The resemblance of this conglomerate to the so-called 'False-Cotham'[2] is still more striking, for the shape, colouring, and irregular lie of the thin, tabular fragments are identical in the two rocks. The main differences are that, in the conglomerate, the smaller fragments are frequently rounded, and the matrix is dissimilar in character from the fragments which it cements. In 'False-Cotham' the fragments are almost invariably tabular, very

[1] See Beeby Thompson, 'Landscape Marble' Quart. Journ. Geol. Soc. vol. l (1894) p. 399.

[2] The term 'False-Cotham' was, I believe, first employed by Mr. J. Parsons, B.Sc., F.G.S.

slightly rounded at the ends, and the matrix is usually of the same texture as the fragments which are embedded in it.[1]

The similarity of the two rocks can be completely explained on the supposition that both have been formed by the breaking-up of Cotham Marble[2]; while the differences seem to accord with the assumption that the 'False-Cotham' was formed by the partial breaking-up of the Cotham Marble at intervals during a continuous phase of deposition, whereas the Sedbury-Cliff conglomerate was formed by the complete break-up of the layer of Cotham Marble after the phase of deposition which produced it had entirely ceased at that place.

We have, then, evidence that a rock-layer lithologically similar to the Cotham Marble was laid down in the Sedbury area, but subsequently broken up and cemented into a conglomerate.

The time occupied by the hardening of the Cotham layer, its destruction, and subsequent cementation into a conglomerate may be considered to correspond roughly to the time of deposition of the White Lias in the areas on the south and east. The Kelston-Station cutting, on the Midland Railway between Bristol and Bath, lies some 20 miles from Sedbury Cliff in a direction south 30° east; and the Stoke-Gifford cutting, on the new South Wales Direct Line, lies almost exactly halfway between the two. At Kelston Station there is, above the Cotham Marble, a considerable thickness of White Lias, capped by the thick Sun-Bed[3]; at Stoke Gifford, the Sun-Bed lies immediately upon the Cotham Marble[4]; while at Sedbury Cliff the White Lias is entirely missing, and is replaced by the conglomerate, made up of fragments of Cotham Marble. The section at Redland (a suburb of Bristol) supplies a link between the Kelston and Stoke-Gifford sections, for at that place there is less than 2 feet of rubbly White Lias between the Sun-Bed and the Cotham Marble.[5] In the cutting south of Chipping Sodbury, on the South Wales Direct Line, situated about $7\frac{1}{2}$ miles east of Stoke Gifford, the White Lias is (as at Stoke Gifford) represented only by the Sun-Bed, which rests immediately upon a precisely similar layer of typical Cotham Marble.[6]

Without attempting any final explanation of the exact conditions of deposition which resulted in the production of the Cotham Marble, it may, with great probability, be assumed that these conditions were practically identical wherever the rock is found. In other words, it seems probable that the whole area over which the Cotham Marble extended was, simultaneously, at approximately the same depth and subject to

[1] I am much indebted to the kindness of Mr. W. H. Wickes for the opportunity of examining several fine specimens of 'False-Cotham' from Redland, Stoke Gifford, and Aust Cliff.

[2] The suggestion that 'False-Cotham' was formed by the breaking-up of Cotham Marble was first made by Mr. A. Rendle Short, B.Sc.

[3] Proc. Bristol Nat. Soc. vol. x (1901) p. 35.

[4] Quart. Journ. Geol. Soc. vol. lviii (1902) p. 727.

[5] Proc. Bristol Nat. Soc. vol. x (1901) p. 38.

[6] Quart. Journ. Geol. Soc. vol. lviii (1902) p. 719.

the same type of deposition: this may be expressed by saying that the whole area was in horizontal equilibrium.

The actual limits of the area covered by the Cotham Marble cannot be definitely ascertained, but it certainly extended southward into the Radstock area.

At Sedbury Cliff the deposition of the Cotham Marble must have been succeeded by an elevation of the floor, which produced the breaking-up of the Cotham-Marble layer *in situ*.[1] It seems to me improbable that the Cotham-Marble deposit indicates any considerable depth of water, for, in the 'False-Cotham,' we have apparent evidence of one or more interruptions, when the layers already formed were partly broken up, after which the conditions of deposition were immediately resumed.

Farther south the Cotham Marble is immediately succeeded by a fine-grained, slabby, impure limestone (the White Lias) which increases uniformly in thickness as far as the Radstock area. The constitution of the White Lias is practically the same as that of the Cotham Marble, and consequently implies little alteration in the manner of deposition.

If we imagine a gradual tilt of the horizontal floor to take place, immediately after the Cotham-Marble deposition, and to have been so performed that the axis of rotation was a line running a little south of Sedbury Cliff, from west slightly south to east slightly north, the result would be a gradual and uniformly-increasing depression towards the south, and an elevation towards the north. If, further, the rate of deposition towards the south approximately kept pace with the rate of depression, we should obtain a result exactly satisfied by all the conditions of the problem. This phase, characterized by gradually-thickening deposition towards the south and actual destruction of deposits towards the north, was succeeded by a period of equal rate of deposition over the entire area, for the *Pleuromya*-Beds (which succeed the White Lias towards the south, and lie upon the conglomerate at Sedbury Cliff) exhibit a remarkably-uniform lithological aspect throughout the area, and contain almost precisely the same fauna, with the same relative vertical distribution, whether they are studied at Kelston, at Redland, at Stoke Gifford, at Sodbury, or at Sedbury Cliff; the actual thickness of the beds is also very nearly the same throughout the area.

Here, then, we have a second period of horizontal equilibrium.

The higher beds of the Lower Lias, which compose the *Psilonotus*-, *Angulatus*-, and *Arietes*-zones,[2] point to a change of axis of rotation and reversed oscillation; for they exhibit gradually-increasing

[1] The large, slab-like fragments, the angles of which are frequently quite sharp, prove conclusively that the conglomerate was made by the breaking-up of material on the spot, and not of material brought from any distance.

[2] An explanation of the connotation of these zonal terms is given in my paper on the Lias of Keynsham, Proc. Bristol Nat. Soc. vol. x (1901) pp. 14 *et seqq.*

thickness of deposit to the north, and diminution of deposit to the south. At Keynsham the deposits included in all three zones reach a thickness of about 35 feet, at Sodbury of about 90 feet,[1] while at Sedbury Cliff no fossils characteristic of beds higher than the upper *Psilonotus*-zone were observed, nothwithstanding the fact that the thickness of the rocks above the *Pleuromya*-Beds amounts to 30 feet. This may perhaps be best explained by supposing a gradual depression of the whole area round an axis, running nearly east and west, somewhat to the south of the Radstock area, and therefore practically coinciding with the Mendip anticlinal axis.

Although the beds composing these three zones at Radstock are almost entirely made up of limestones, it cannot be deduced as a necessary consequence that the depth of the floor at Radstock was greater than in the area farther north, where the greater part of the deposit is made up of shale. The similarity of the fauna and the nature of the shale-partings, whether thick or thin, suggest the practical identity of bathymetrical conditions throughout the area. The preponderance of limestones towards the south seems merely to imply proximity to a land-area, composed of limestone-rocks, such as the Mendip ridge would naturally have supplied.

2. The Relative Faunal Sequence at Sedbury Cliff.

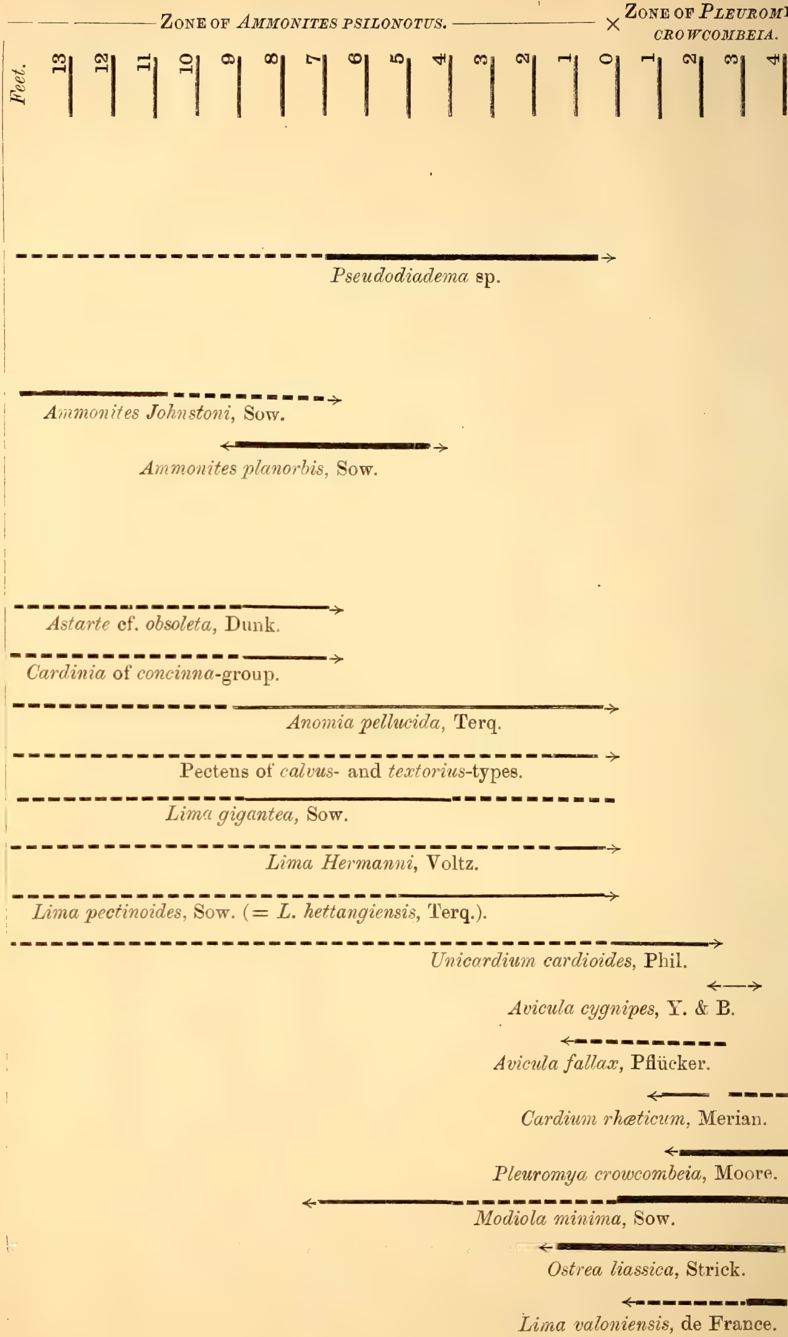
Owing to the inaccessibility of the upper beds, we were only able to study in detail the lower 12 feet of Lias, but, since fallen fragments of all the higher beds are to be found on the shore, there is very strong negative evidence that no beds above the *Psilonotus*-zone are represented throughout the 35 feet of Lias in the cliff, for no fossils characteristic of the *Angulatus*-zone could be found.

The accompanying range-diagram (p. 400) scarcely calls for explanation. The continuous portion of any ordinate indicates the beds throughout which the species is continuously abundant; the interrupted portions indicate those beds in which it either occurs only sparingly, or which intervene between two zones of abundance. The extremities of each ordinate simply mark the point at which the species begins or ceases to occur in sufficient numbers for its presence to be recognized without exhaustive search (so that an exceptional early-arrival or late-survivor is disregarded); since we are mainly dealing with species immensely prolific in individuals, there is little difficulty in fixing the extremities of the range-ordinates.

As already remarked, the fauna of the lowest beds is almost precisely identical throughout the area which includes Sedbury Cliff, Sodbury, Stoke Gifford, Kelston, and Bristol; and, moreover, the vertical distribution within those beds is remarkably similar.[2]

[1] Proc. Bristol Nat. Soc. vol. x (1901) p. 22.
[2] *Ibid.* p. 3.

Diagram[1] showing the ranges of Fossils through the Lowest Beds of the Lower Lias at Sedbury Cliff.



[1] [This diagram was originally described as a 'range-graph'; but I readily take this opportunity of withdrawing the term; partly in deference to Sir Archibald Geikie's strongly expressed objection (see Discussion, p. 402), and partly because such diagrams are not strictly 'graphs' in the common technical use of that term. A graph represents geometrically the change in some function of a continuous variable, whereas the ordinates of a range-diagram are, of course, entirely independent of their relative positions.—*July 18th, 1903.*]

At Sedbury Cliff specimens of *Ostrea liassica*, *Modiola minima*, and *Pleuromya crowcombeia* crowd the lowest 4 feet, and with them are associated, in certain layers which occupy the same relative position as at other points throughout the area, abundant specimens of *Cardium rhæticum* and *Unicardium cardioides*. The strongly-ribbed *Lima valoniensis* is also very common, and *Avicula cygnipes* occupies its usual position near the very base; *Avicula fallax* is not common, and no example of *Pholadomya glabra* was discovered throughout the section.

The succeeding beds exhibit a considerable faunal change, for *Lima gigantea*, *L. Hermanni*, and *L. pectinoides*[1] enter and immediately become abundant, Pectens of the *calvus*- and *textorius*-types become common, while the shales are crowded with *Anomia* and fragments of a *Pseudodiadema*. Of the forms which characterize the zone of *Pleuromya crowcombeia*, only *Ostrea liassica* and *Modiola minima* pass up into these beds, and here *M. minima* occurs very sparingly, while *O. liassica* is abundant only at the base.

Hence it seems best to make the zonal division at this point, rather than to carry the lower zone up to the first entrance of *Ammonites planorbis*, which does not take place until some 4 feet higher, at a level that marks no other important palæontological change. The beds which contain *Am. planorbis* differ in no other respect from those just below, and, in particular, the shales are wonderfully uniform in their fossil contents, throughout the whole series of beds above the suggested division.

If this zonal division be adopted, the best index for the lower zone is certainly *Pleuromya crowcombeia*, for the reasons suggested by me in the paper on the Keynsham Lias already referred to. This is by no means a new suggestion, for the term '*Pleuromya*-Beds' for the beds of the Lias has long been in use.[2]

The whole of the beds above this division at Sedbury Cliff are, then, best grouped together as belonging to the *Psilonotus*-zone, notwithstanding the absence (or extreme rarity) of ammonites from the lowest 4 feet.

A point of some interest in the faunal sequence is the fact that, at Sedbury Cliff, the first occurrence of ammonites, in any abundance, does not occupy quite the same relative position as it does farther south.

If we compare the range-diagram given in this paper with that given in the paper on the Lias of Keynsham, we see that, whereas the relative ranges of the most commonly-occurring lamellibranchs agree very closely in the two cases, *Ammonites planorbis* enters relatively later at Sedbury and persists relatively longer.[3]

[1] =*L. hettangiensis*; see Proc. Bristol Nat. Soc. vol. x (1901) p. 49.

[2] See Tate & Blake's 'Yorkshire Lias' 1876, chapt. vi, pp. 39–45.

[3] I here use the name *Ammonites planorbis* to imply the smooth form of *Am. psilonotus* which has a moderate growth-rate, as distinguished from the strongly-ribbed *Am. Johnstoni* with a slow growth-rate. The specimens of *Am. planorbis* are ill-preserved at Sedbury Cliff, and especially so in the bed

It may be hoped that the construction of range-diagrams dealing only with the periods during which a common species was abundant (and therefore independent of any small error in observation), will be of use in testing the value of a series of ammonite-ages as divisions of relative time. The errors to which such a series seems *a priori* liable, are (1) irrationality or lack of proportion—that is, the ratio of any two successive ranges is not the same in two different localities; and (2) acceleration or retardation of the ammonite-ages,[1] when measured against the variation of longer-lived forms.

Discussion.

Mr. H. B. Woodward said that the careful observations of the Author could not fail to be of great service. With regard to the extent of the Cotham Marble, it occurred not only over the Radstock area but southward into Dorset.

The Chairman (Sir Archibald Geikie) said that he would not prolong the discussion, but would like to enter his protest against the introduction of such a barbarism as 'range-graph' into geological terminology. Men of science were sometimes censured for their indifference to literary requirements and their love of a cacophonous nomenclature, and geologists had to bear their full share of this reproach. He hoped that the Author would find some other term that would equally express his meaning, and give no cause of offence to those who would like to keep the well of English undefiled.

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which is crowded with them: here they occur as flattened, iron-stained casts, but the absence of any recognizable trace of ribbing and the growth-rate, so similar to that of the specimens from Watchett, make their identification almost certain. This is further confirmed by comparing the specimens from a similar horizon at Stoke Gifford, where they occur in the same abundance and in a similar ferruginous matrix, but are somewhat better preserved.

Although I was not fortunate enough to confirm the observation at the time of our joint visit to Sedbury Cliff, Mr. Richardson had noted on a previous occasion the occurrence of *Ammonites Johnstoni* in a bed lying well within the range of *Am. planorbis* and in which I found undoubted specimens of the latter form. Though I have never actually observed *Am. planorbis* and *Am. Johnstoni* occurring together in the same bed, yet the early occurrence of the latter at Sodbury goes far to confirm the accuracy of Mr. Richardson's observation. There is no doubt, however, that, at Sedbury Cliff, as in the whole of the area to the south and east, the zone of abundance of *Ammonites Johnstoni* occurs in the beds above those containing *Am. planorbis*.

[1] The term 'age' is used instead of 'hemera,' as simply implying the period during which a species flourished at any locality, without for a moment suggesting that this period is the same astronomical epoch at two different localities.

33. DESCRIPTION *of a* SPECIES *of HETERASTRÆA from the* LOWER RHÆTIC *of* GLOUCESTERSHIRE. By ROBERT F. TOMES, Esq., F.G.S. (Read May 13th, 1903.)

I HAVE been favoured by Mr. L. Richardson, F.G.S., of Cheltenham, with the loan of a small compound coral which he took from the Lower Rhætic Beds at Deerhurst (Gloucestershire). It is undoubtedly a species of *Heterastræa*, differing chiefly from the several Liassic species in the small size of the corallum, and in the small size of its calices. Mr. Richardson writes of its locality and stratigraphical position as follows :—

'The exposure where the coral was obtained is situated about three-quarters of a mile east-south-east of Deerhurst Church, in a deeply-cut wheel-track. The gate giving access to this track is almost opposite a barn which is situated less than a quarter of a mile south-west of 'The Folly.' The Upper Keuper red marls constitute the subsoil of the field, and in the bank opposite the oak-tree the Tea-green Marls are visible. In the winter of 1901 the following beds were revealed by a very little excavating, but unfortunately the measurements were not taken; now the exposure is overgrown (August 1902):—

		Thickness in inches.
I. UPPER RHÆTIC.	Greenish-yellow marls.	
II. LOWER RHÆTIC.	Shales, black.	
	Sandstones, hard, grey, calcareous; lamellibranchs and coral	1
	Shales, black.	
	Sandstone, Bone-Bed equivalent; brown, micaceous, *Schizodus (?), Acrodus minimus*	4
	Shales, firm, black.	
III. UPPER KEUPER.	Tea-green Marls.	
	Red Marls.	

'The nearest section where details of the above deposits can be obtained is at Coomb Hill, 1½ miles distant. Here the equivalent beds attain the following thickness:—

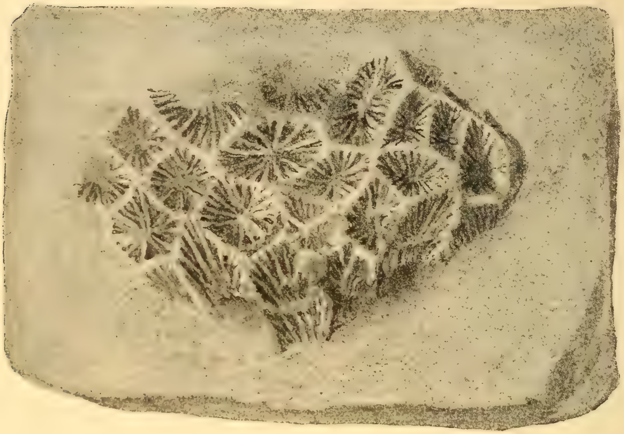
		Feet	*inches.*
LOWER RHÆTIC.	Shales	1	0
	Sandstone	0	2
	Shales	1	6
	Sandstone, Bone-Bed	0	3
	Shales	2	0
UPPER KEUPER.	Tea-green Marls.		
	Red Marls.'		

From the foregoing it is evident that the coral occurs only a very little way above the Bone-Bed, which there, as in many other places, is a hard micaceous sandstone. It is specifically new, and generically new to the Rhætic formation, and, as I shall presently show, has a very Jurassic relationship. I describe it as follows :—

HETERASTRÆA RHÆTICA, sp. nov. (figs. 1 & 2, p. 404).

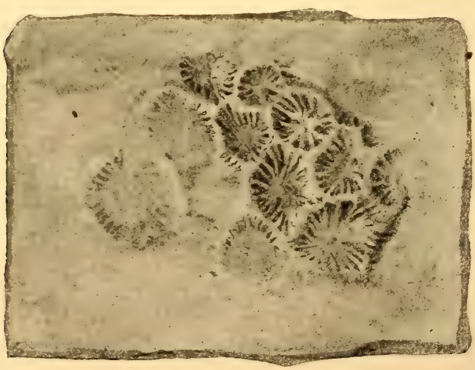
The corallum, as is so commonly the case with the compound corals of the Rhætic deposits, is small, and, so far as may be determined

Fig. 1.—Heterastræa rhætica, *sp. nov., showing, by the serial calices, the growth by fissiparity.* × *3.*



F. H. Michael del.

Fig. 2.—Heterastræa rhætica, *sp. nov., showing, by the small rounded calices in the upper part of the figure, the growth by gemmation.* × *3.*



F. H. Michael del.

by the much-embedded specimen, has a somewhat peduncular form, with a spreading and gibbous or lobed upper or calicular surface. There are two portions exposed which are near together, and may be taken as parts of the same corallum. The larger one consists of twenty calices (fig. 1, p. 404) which are well defined; and the smaller one has eight calices (fig. 2), which scarcely project above the level of the matrix, and exhibit evidence of having been worn down. A portion of the side of the corallum is exposed, showing indications of a common wall and rudimentary costæ, but no epitheca. It bears great resemblance to the peduncular parts of *Elysastræa* as figured by Laube.[1]

All the calices are small and irregular, both in size and form, the largest not exceeding 2 lines in diameter, and the smaller being of only half that size. They are more or less lozenge-shaped, and there is a distinct interval observable between two of them, due to the imperfect union of the corallites. Between all the others there is a thick and prominent wall. All the calices are of medium depth.

In a well-developed calyx there are six systems and three cycles of septa, with a rudimentary fourth. All the septa exhibit the peculiarity common to several Rhætic Madreporaria, of being thin at their connection with the wall and becoming thicker as they approach the fossula. Those of the first and second cycles meet and unite in the fossula; those of the third are three-fourths the length of those of the first; while the septa of the fourth cycle are irregular in length, as well as in their degree of development.

The margins of the septa, though somewhat worn, present a rounded outline and are denticulated, the denticulations being few in number, not more than six or seven on the longest septum. There are a few dissepiments which almost assume the character of tabulæ.

Both gemmation and fissiparity are very obvious on the upper surface of the corallum.

	Inches	*lines.*
Height of the corallum, probably	0	9
Greatest diameter of the same, about	1	2
Diameter of the largest single calyx	0	2

Since the definition of *Heterastræa* in 1888[2] the genus has been found to extend upward into the Inferior and Great Oolite; and in all the Oolitic species there is a distinct basal or common wall which sometimes has well-defined costæ, but in no instance a trace even of epitheca. In the Liassic species, on which the genus was founded, the wall and its costæ are merely rudimentary.

The elimination of the species of *Heterastræa* from *Isastræa* and *Latimæandra* reduces the species of those genera materially, and at the same time renders their definition, hitherto very loose and unsatisfactory, much more definite and concise.

[1] 'Fauna d. Schichten v. St. Cassian' pt. i (1865) pl. v, fig. 6. (Denkschr. d. k. Akad. d. Wissensch. Wien, vol. xxiv.)

[2] Geol. Mag. 1888, p. 207.

The figures of St. Cassian corals given by Laube[1] have every appearance of truthful delineation, and several of the species have been determined as British. An examination of the figures of *Isastræa Gumbeli* and *I. Hauri* has led me to conclude that the former represents a true *Isastræa*, and the latter a species of *Heterastræa*. From the former the present species differs generically, and from the latter specifically in having much smaller calices.

I avail myself of the present opportunity of adding a few remarks on some other Madreporaria from the Rhætic formation and from the basement-beds of the Lower Lias. The genus *Cyathocœnia* was established by Duncan[2] for some species from the Sutton Stone of Glamorgan, and was identified by me in 1884[3] as generically identical with the coral described and figured by Laube as *Phyllocœnia decipiens* from the Triassic deposits of St. Cassian. Subsequently, but during the same year,[4] Duncan made Laube's species the type of a new genus to which he gave the name of *Koilocœnia*, under the impression that the corallites were surrounded by a second or outer wall. There is not, however, any second wall, but only a break in the costæ connecting the corallites; yet this is by no means a constant character. In the absence of a second wall, there is nothing to distinguish *Koilocœnia* from *Cyathocœnia*.

It has always been my opinion that the Sutton Stone, containing Rhætic Madreporaria, should be classed as Rhætic; indeed, I believe that the above-named deposit is really Upper Rhætic.

Postscript.

[After repeated and protracted search for corals in the Sutton Stone of Glamorgan I have concluded that certain species from that district obtained by myself were undoubtedly Rhætic, and I recorded them as such in vol. xl (1884), at pp. 357–60, of this Journal, to which I now refer. I may, however, add that the species to which I especially refer are the following:—

Montlivaltia perlonga, Laube.
Thecosmilia rugosa, Laube.
Cladophyllia sublævis, Laube.
Elysastræa Fischeri, Laube.
Calamophyllia cassiana, Laube.
Phyllocœnia decipiens, Laube.

All these have been obtained by me from the bottom of the Sutton Stone, and almost in actual contact with the floor of Mountain-Limestone, but at one spot alone, and that only of very limited extent.

[1] 'Fauna d. Schichten v. St. Cassian' pt. i (1865) pls. iii–vii. (Denkschr. d. k. Akad. d. Wissensch. Wien, vol. xxiv.)
[2] 'Monogr. Brit. Foss. Cor.' pt. iv, no. 1 (1867) p. 27. (Palæont. Soc. vol. xx.)
[3] Quart. Journ. Geol. Soc. vol. xl (1884) p. 372.
[4] Journ. Linn. Soc. (Zool.) vol. xviii (1885) p. 115.

Bearing in mind the very close relationship between the Upper Rhætic and Lower Liassic organisms, and the great importance of the ammonite-zones as a means of classification, it may be asked whether the zone of *Ammonites planorbis* should be taken as the bottom of the Lower Lias, as it most certainly is in many places in Warwickshire, namely at Harbury, Stonythorpe, and Newbold-on-Avon. At the last-named locality I have obtained specimens of *Ammonites Johnstoni* which were lying directly upon the White Lias, indeed in absolute contact with it, and no question has ever arisen as to the latter being Upper Rhætic. At Binton, a few miles west of Stratford-on-Avon, I have collected specimens of *Ammonites planorbis* similarly lying upon the *Ostrea*-bed, but no ammonite has ever been found enclosed in it. The discovery of the present species of coral, having a thoroughly Jurassic relationship, quite low down in the Rhætic Series tends to emphasize yet further the uncertainty of the division between the Liassic and Rhætic formations.—*July 21st, 1903.*]

Discussion.

The Rev. H. H. Winwood expressed his surprise to hear the question of the age of the Sutton-Stone Series brought up again. He thought that controversy was buried long ago. He challenged the statement that the Series contained Rhætic corals: P. M. Duncan, Charles Moore, and H. W. Bristow had satisfactorily proved that the fauna was Liassic, as at least three characteristic fossils of that formation—namely, *Gryphœa incurva*, *Ostrea liassica*, and *Lima gigantea*—may be traced from bottom to top of those beds.

Mr. H. B. Woodward remarked that, as ammonites of the *planorbis*-group occurred in the Sutton Stone, and had been found by the previous speaker in equivalent beds of like character at Shepton Mallet, he could not understand the grouping proposed by the Author.

The Rev. J. F. Blake said he thought that the Liassic age of the Sutton Stone had long ago been determined.

34. *The* GEOLOGY *of the* TINTAGEL *and* DAVIDSTOW DISTRICT (NORTHERN CORNWALL). By JOHN PARKINSON, Esq., F.G.S. (Read March 25th, 1903.)

[PLATE XXV—MAP.]

CONTENTS.

INTRODUCTION.

SINCE the publication in 1839 of the far-famed Memoir by Sir Henry de la Beche on the 'Geology of Cornwall, Devon & West Somerset,'[1] a large part of the first-named county has been left comparatively unmolested, alike by the hammer and by the theories of the geologist. Thus the district which lies to the westward of the fossiliferous Upper Devonian Beds of South Petherwin and Landlake, from St. Clether, in a westerly direction, *via* Davidstow and the North Cornwall branch of the London & South-Western Railway to the coast, has been almost untouched, except for four papers, since the date above mentioned. These are

S. R. PATTISON. 'On Auriferous Quartz-rock in North Cornwall' Quart. Journ. Geol. Soc. vol. x (1854) p. 247.
H. B. HOLL. Quart. Journ. Geol. Soc. vol. xxiv (1868) pp. 418–19.
J. A. PHILLIPS. 'On the so-called "Greenstones" of Central & Eastern Cornwall' Quart. Journ. Geol. Soc. vol. xxxiv (1878) p. 471.
W. MAYNARD HUTCHINGS. Geol. Mag. dec. iii, vol. vi (1889) pp. 53, 101, & 214.

My sincere thanks are due to Prof. T. G. Bonney, F.R.S., for kind suggestions in the course of the preparation of this paper; to Lieut.-Gen. C. A. MacMahon, F.R.S., for the loan of slides of the Cock's Tor rock; to Miss Raisin, D.Sc., for specimens and slides from the Ardennes; to Mr. G. T. Prior and Dr. J. S. Flett, for invaluable aid in determining some of the minerals; and to Mr. E. T. Newton, F.R.S., for kind help with the fossils. These are, from the coast east of Tintagel Head (between Barras Gug and Smith's Cliff) forms comparable with *Atrypa flabellata* and with *Posidonomya*; and *Spirifera Verneuilii*[2] from Lanterdan Quarry.

A list of fossils from Tintagel was given by Holl.

PART I.—(*a*) DESCRIPTION OF THE DISTRICT.

In regard to the general structure of the country, two points are of

[1] Pp. 56–59, 108.

[2] Recorded also by S. R. Pattison from the neighbourhood of Trevivian Farm, Quart. Journ. Geol. Soc. vol. x (1854) p. 247.

great importance. Firstly, from St. Clether on the east to the Rocky Valley on the west, the regularity of the strike which trends east-south-eastward and west-north-westward is the most conspicuous stratigraphical feature; and secondly, that—more or less out of their position as determined by the above-given strike—all the higher beds come in along the coast from the Rocky Valley to Trebarwith Strand, the most southerly point touched. This arrangement appears due partly to a change in dip from a northerly to a westerly direction—producing a kind of hemidome; and partly to north-north-easterly faults.

The geological structure is reflected by the aspect of the country. Thus, looking inland from some point on the cliffs between Trebarwith Strand and Trevena, we see a plain, consisting of the higher beds, greatly disturbed, rising almost inappreciably to the east as far as a north-and-south line joining Trenale, Downrow, and Trebarwith.

Abruptly beyond this line rise the hills on which lie Trenalebury Camp and Meneden, consisting of beds having the normal east-south-easterly and west-north-westerly disposition. The plain is broken to the north by the Rocky Valley, northward of which again the ground slopes with a gradually-falling profile from Tregatherel to Trambley Cove and the Saddle Rocks.

Along this strip of country the orderly sequence of beds is preserved, and the east-south-easterly and west-north-westerly strike continued to sea-level; but on the south, as above remarked, where the hills rise from the flat coast, a region of extensive faulting appears to separate the folded beds near the sea from those of more regular disposition to the eastward.

The mineralogical composition of the beds may be responsible for the not uncommon absence of conspicuous effects of pressure. Taken as a whole, the greater mass consists of comparatively-soft sedimentary rocks, usually built up of closely-matted flakes of white mica, and resembling the phyllites of the Ardennes. On one horizon they are banded (as, for example, at Hallwell Cottage, Benoath Cove, Trewassa), and here the bands commonly are not contorted. Although a reconstruction of the original sediment[1] on the whole must have preceded pressure, examination of thin sections does not invariably show clear evidence of such a sequence, probably, in many instances, owing to a later mineral reconstruction which has masked the effects of pressure. This is also usually true of the Volcanic Series. When, however, we examine the Blue-Black Slates overlying the Volcanic Series we generally find, not only intense contortion in the more finely-banded members, but that occasionally crushing has been sufficient to reduce the rock to the condition of a fault-breccia.

The cliffs to the south of Trambley Cove (west of Trevalga) are a case in point. Here the Blue-Black Slates lie in their proper position between the Volcanic Series below, and softer greenish phyllites with white spots above; but the slates form a mere zone in the cliff, the

[1] See W. M. Hutchings, Geol. Mag. 1889, pp. 106, 107.

beds of the Volcanic Series abutting abruptly on their contorted face. Locally, they are a fault-breccia without semblance of stratification.

A field-quarry some two-thirds of a mile to the east-south-east on the line of strike shows intense cortortion and brecciation in the same hard slates, although not quite equalling the Trambley-Cove exposure.

Pursuing the same direction, finely-banded slates and slate-breccia are found between Tredole and Tregania, occupying the same position in regard to the under- and overlying beds. A small quarry between Tregrylls and Gunvillick displays an identical rock in an identical state.

Quitting the true line of strike, we find the same slates at Gullastem, greatly contorted and crushed. Between that inlet and Barras Gug they are in places reduced to a state of breccia.

Between Lill Cove and Vean Hole, about 300 yards north of Trebarwith Strand, may be found important structures indicative of the same tremendous pressure. At the former place the Tredorn Beds, forming the top of the cliff, are reduced to a structureless state, without sign either of bedding- or joint-planes; below lies a zone, some 20 inches thick, composed of the intensely contorted Blue-Black Slates, interlaminated with some paler softer beds, similar to those above, the whole affording a transition from one group to the other. Below the contorted zone lies an undisturbed belt of the same Blue-Black Slates. Application of great pressure has clearly taken place, resulting in a slide at the junction of the hard and soft rocks, where its effects are most obviously displayed in the contorted zone.

Somewhat similar structures have been produced at Vean Hole, the direct continuation of the same slide. Two bands of the black slate, some 10 inches thick, form, as seen in the cliff-section, a series of three or four ellipses joined the one to the other like the links of a chain. The rock forming the centres of the ellipses is almost white, hard, somewhat brittle, and apparently a reconstructed band of the overlying phyllites impregnated with quartz. Numerous quartz-eyes appear in it. Above, the whole grades into the Tredorn Beds; below, into the Volcanic Series. Intense crushing is shown also at Lye Head, Tintagel Head, and to the east of Smith's Cliff.

The low dip of the beds at Lill Cove seems opposed, at first sight, either to great pressure or much differential movement. The rocks of Willapark (the western side of Bossiney Haven) present a somewhat similar appearance. Two dip-faults, combined to form a **V**, bring in the Tredorn Beds and the Upper Blue-Black Slates. Examination of the shore, however, shows that the movement has been not merely vertical, but more or less parallel with the bedding, where its greatest effects are exhibited near the junction of the Blue Slates and the Tredorn phyllites.

These facts, taken in conjunction with the great crushing from Trambley Cove eastward (described above) make it probable that intense compression affected the entire region; but, the present dip being once acquired, motion took place most readily along the directions of bedding.

(b) Macroscopical Description of the Rocks.

The Tredorn Beds.

The uppermost beds of the series of rocks described in the present paper have been traced from Abbott's Hendra near St. Clether to the coast, a distance of about 8 miles. Taken as a whole, they are light bluish or greenish-grey phyllites, with slightly marked foliation-surfaces; usually soft enough to be scratched by the nail, and often speckled by elliptical rust-red spots. Occasionally they are dull greyish-black, either splitting readily into thin sheets, or, locally, into less well-defined slabs.

From the London & South-Western Railway to the coast, small white spots (probably of orthoclase) are characteristic of these slates; east of the railway they have not, so far, been found (Abbott's Hendra type, identical with the slate of Caroline Quarry on the coast).

In the western part of the district these rocks near their base, that is, near to the Upper Blue-Black Slates, recall the underlying Hallwell-Cottage Beds; while the latter in their uppermost part, that is, near to the Lower Blue-Black Slates, are often white-spotted, and recall the Tredorn Beds. At Caroline Quarry, north of Trebarwith Strand, the rock is a dull, greenish-grey, fossiliferous slate, with a rather ropy fracture, whereas close by at Lanterdan Quarry it is darker, more slaty, and, on the whole, harder; a common type, recalling many other rocks from very different horizons.

The Volcanic Series.

These are blue-greyish, or, more commonly, greenish rocks, varying much in appearance from point to point, but possessing characters which, as a whole, clearly separate them from beds above and below. Schistose structure is generally very marked; foliation-surfaces glitter with brown or bronze-coloured mica-scales, which often are rather patchily distributed, and not infrequently are associated with crystals of epidote.

A banded or lenticular structure is locally very conspicuous, occasioned by the presence of carbonates; and crystals of felspar catch the eye in a few specimens.

The result of decomposition in these rocks is to produce a characteristic, very fine, bluish mud usually containing mica, which is of great help in mapping where exposures are scarce. With rocks of this type are associated, on the one hand, many more slaty in character; on the other, specimens strongly recalling the German schalsteins.

This somewhat heterogeneous group is termed the 'Volcanic Series,' and has been found to afford a well-marked datum-line, which, in the great majority of instances, may be readily recognized from fragmentary exposures. To this rule, however, may be found local exceptions, as, for example, in the neighbourhood of Trambley Cove. There, these rocks are hard and slaty, no doubt of the nature of passage-beds below the Upper Blue-Black Slates, but differing considerably from the typical members of the Volcanic Group. At

such a junction thin beds of ashes or small lava-flows are often interbedded with the Black Slates, as, for example, to the east of Barras Gug, where they are not more than a few inches thick, and continue horizontally only for 10 or 12 feet.

Quite possibly the rocks of the Volcanic Series may include later basic intrusions, which have not yet been separated.

At Barras Nose magnetite is locally very conspicuous, and on Smith's Cliff rectangular crystals of marcasite three-eighths to half an inch long are scattered through the rock.

Above and below the Volcanic Series are the readily recognizable Upper and Lower Blue-Black Slates; but the arrangement of the remaining beds is attended with some difficulty, owing to the variation in the petrographical characters and the resemblances often found between rocks of different horizons.

The group underlying the lower slates, towards the [1] Hallwell-Cottage Beds, is distinguished, when typically developed, by a fine banding, accompanied, however, by considerable variation from point to point. The rocks contain a clinochlore resembling ottrelite.

Good examples may be seen in the neighbourhood of Bossiney Haven, parts of the Rocky Valley, Hallwell Cottage, Trewassa, etc. These rocks are pale-grey in colour, speckled with unoriented crystals of clinochlore, resembling carraway-seeds in the hand-specimen. With a lens minute black specks of hæmatite can be made out, and the mass of the rock has a saccharoidal appearance, by reason of the interwoven flakes of sericite of which it is composed. Such rocks are sufficiently soft to be marked by the nail, but they are often darker in colour, and then commonly harder.

Aggregation of clinochlore and filmy chlorite along certain lines gives rises to the typical banding, and the lighter-coloured parts not infrequently contain quartz-grains. These typical members of the Hallwell-Cottage Beds are associated with unbanded dark and more slaty rocks without clinochlore, breaking under the hammer into sheets about three-sixteenths of an inch thick. Their foliation-surfaces feebly reflect the light, and examination with a lens shows them to be crystalline. Locally, they are speckled with small white spots (as, for example, at Treknow and Redevallen), and then recall the Tredorn Beds. Frequently these dark slaty rocks occur immediately below the Lower Blue-Black Slates, as, for instance, on the eastern side of the mouth of the Rocky Valley.

Between the sea, at this point, and Trewethet the more typical clinochlore-bearing beds come in at intervals along the side of the valley and on the banks of the stream.

On the east side of Bossiney Haven, the next inlet to the west, well-banded beds occur immediately below the Lower Blue-Black

[1] On the 1-inch map midway between Hendra and the South-Western Railway, $1\frac{1}{4}$ miles north-west of Davidstow Church. Mr. Hutchings has described ottrelite from near Tintagel Church, a part of the district that I have not examined: see Geol. Mag. 1889, p. 215.

Slates, and may be traced down to the shore, with the exception of the middle third of the cliff, where their place is taken by the dark slaty variety. The typical rocks, therefore, are found with considerable irregularity. In the same way, the road from the Prince of Wales's Quarry to Treknow Mill [1] passes through a series of rocks mapped as Hallwell-Cottage Beds, and these, locally (as, for example, east of the Mill Road), are excellently banded. No doubt the whole is approximately on one horizon. Nevertheless, not only are the beds themselves variable, but here, as in other places, the true order may be confused by small faults, which are inappreciable because exact horizons are difficult to determine. Over Waterpit Downs and north-west of Condolden surface-indications are all that are available, and the position of the underlying beds may be most readily determined by the presence of a dark slabby rock, with lustrous fracture-faces and a fibrous structure produced by the orientation of its crystals of white mica (p. 424). This rock is found *in situ* in the railway-cutting which lies to the west of Hendraburnick Farm, and is considered as part of the Hallwell-Cottage Series.

The underlying rocks (Penpethy Beds and Slaughterbridge Beds), as well as the epidiorites, are described in Part II. Overlying the Tredorn Beds are carbonaceous blue slates, well developed in the neighbourhood of Lesnewth. They have not been studied by me, and are not described in this paper.

In the petrographical description which follows, the beds are taken in descending sequence, with the exception of the Upper and Lower Blue-Black Slates, which are described together near the end of the paper.

Part II.—Description of Microscopical Detail.

The Tredorn Beds.

The rocks from the following localities form a well-marked type:—Abbott's Hendra Farm, north-west of St. Clether, the small quarry to the south of Hallworthy, Treegreen Farm, the road south of Otterham Station, parts of the South-Western Railway-cutting near Lesnewth, and Lanterdan Quarry on the coast. Thin sections show these rocks to be fine-grained and rather opaque phyllites, composed of minute flakes of a pale-green chlorite and sericite, set in a translucent base which, in many instances, appears to be isotropic. Specks of iron-oxide are common, and for the most part are hæmatite; but ilmenite occurs, frequently showing excellent sagenitic rutile. Tourmaline, rutile-grains, and, locally, minerals resembling ottrelite and colourless garnet are accessories.

The rock found north of the farm of Tregrylls, on the road to Lesnewth, affords an instance of a second type of the Tredorn phyllites, and one which is characteristic of these beds westward as far as the coast. The Tregrylls rock is harder than the Abbott's-Hendra type, of a slabby fracture, dark slate-grey in colour, and

[1] The road from Camelford Station to Trebarwith Strand.

closely speckled with small dull-white spots about ·01 inch in length. The matrix in which these spots are set consists of a felted mass of chlorite, through which are scattered conspicuous flakes of white mica, and many of ilmenite.

Dr. Flett and Mr. Prior have kindly looked at slides and specimens from Tregrylls and the coast south of Boscastle, containing the characteristic white mineral. The following are its optical properties :—It is biaxial and negative, quite translucent, unaffected by heating to bright redness, cleavage is absent, the refringence and birefringence are low. Minute inclusions (mica and iron-oxides) are arranged parallel or nearly parallel to the longer axis of the mineral, and extinction measured in regard to their direction of orientation is invariably oblique. Twinning on a simple plan occurs here and there, but is not well marked. Mr. Prior tells me that the specific gravity is

'near that of beryl, 2·69, the grains scratch calcite and even apatite, and the mineral is not decomposed by sulphuric acid, but a few grains yielded to sulphuric and hydrofluoric acids.'

The mineral is probably orthoclase.

The Volcanic Series.

The banks of the River Inny, near St. Clether, afford numerous examples of amygdaloidal volcanic rocks of a type which is also found near Davidstow, at Trewinnow, and in the South-Western Railway-cutting. The typical rock of St. Clether consists of flakes of chlorite and mica, of opacite, and iron-oxides set in a translucent 'base,' which assumes a finely speckled appearance between crossed nicols.

Comparison of numerous thin sections show this to be partly felspar, partly quartz. In this 'base' yellowish granules, probably of epidote, have formed, with sphene, an almost colourless hornblende, magnetite, and probably leucoxene in some sections. Lath-shaped crystals of a plagioclase are not rare.

A similar rock (though differing in appearance macroscopically) is characteristic in appearance and structure. Markedly foliated, slabby in fracture, and of a greenish-grey colour, it is especially distinguished by dark-green oval spots, which the microscope shows to be amygdaloids flattened by pressure. The body of the rock consists of chloritic needles and flakes, sometimes densely aggregated, sometimes opening to show a small grain of quartz or secondary felspar, but a considerable proportion of this pale flesh-coloured base is isotropic. Opacite, magnetite, etc., are disseminated evenly enough throughout, and rutile occurs as a rare accessory. The amygdaloids are composed of quartz, chlorite, chalcedony, and magnetite. In many localities this rock is associated with a hard ashy-looking slate, containing lenticular black patches of magnetite-dust—locally titaniferous, the particles sometimes densely aggregated to the exclusion of foreign material, at others forming idiomorphic crystals. In some slides all stages in the concentration of the mineral may be traced, from a cloudy dissemination to a dense mass (as, for example, south-east of Treglasta).

Rocks belonging to the Volcanic Series are found to the south of

Tregrylls Farm, and form in some degree a connection between those above described and others, more altered, to be mentioned later.

Two specimens have been sliced; the one contains some quantity of impure sphene and idiomorphic crystals of epidote,[1] sufficiently large to be visible to the unaided eye; the other, while resembling it in the possession of these two minerals, differs in containing a

Fig. 1.—*Crystals of epidote and sphene, with granules of ilmenite, in a groundmass of chlorite and actinolite-flakes,* × *40. South of Tregrylls Farm, on the road to Lesnewth from Waterpit Down.*

greater proportion of dolomite and calcite and well-developed flakes of biotite. The last-named mineral is brownish or yellowish-green for vibrations parallel to the basal plane, and straw-coloured at right angles to this, with a considerable degree of absorption. The orientation of the flakes gives the rock a very schistose appearance.

Crystals of sphene are very numerous in the first slice (fig. 1);

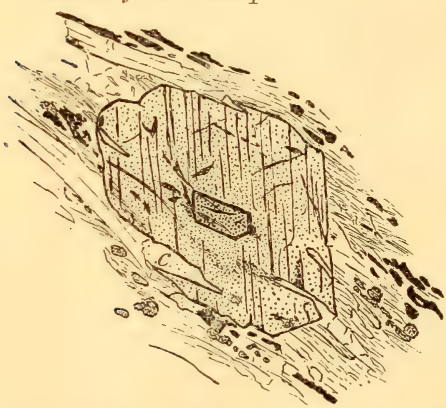
[1] Enclosing allanite, to which reference is made on p. 416.

with a 1-inch objective fifty or more may be found in the field at the same time. Frequently the form is granular, without indication of crystalline faces, but acute-angled rhombs are not uncommon. The mineral is earlier in formation than the epidote. In the latter cleavage is often well marked, the crystals are traversed by numerous cracks, and are occasionally twinned: the pleochroism is feeble.

In these slides the ilmenite and sphene form distinct and separate bands, parallel with the general foliation of the rock. It is inferred that the titanium-oxide present in the original rock has been utilized to form either sphene or ilmenite, according to the local presence or absence of lime. Granules of sphene may often be seen clinging to the ilmenite-grains.

The epidote from some of the rocks hereabouts and from the adjacent South-Western Railway-cutting (No. 91) contains crystals of allanite [1] (fig. 2). The crystalline faces of the allanite are parallel to those of the enclosing mineral, but the orientation is different, for the greater length of the allanite is usually oblique to the greater length of the epidote. Cleavage is absent, the index of refraction is higher than for epidote, the double refraction is considerable, zonal structure does not occur, but the mineral is often rather irregularly coloured. The scheme of pleochroism is difficult to determine, but the colour varies from reddish-brown to pale yellowish-brown, often with a greenish tinge. Extinction takes place parallel to the greater length of the crystal.

Fig. 2.—*Crystal of epidote, enclosing allanite and embayed by calcite (c), × 45. South of Tregrylls Farm, on the road to Lesnewth from Waterpit Down.*



An allied rock from Trehane, near Davidstow Church, contains crystals of tremolite in a 'base' of chlorite and actinolite-flakes; while another from the eastern side of the mouth of the Rocky Valley contains rounded or rectangular translucent felspars up to a tenth of an inch in diameter, and occurring rather as do the garnets of some schists. These felspars appear to be original (that is, not authigenous) constituents which have undergone reconstruction in place. In the chloritic 'base' of the rock are developed a few elongated crystals of secondary hornblende. The pleochroism of this mineral varies from a deep green, very slightly tinged with blue, to a pale yellowish-green. Opacite, incipient sphene, occasional

[1] Compare W. H. Hobbs, Am. Journ. Sci. ser. 3, vol. xxxviii (1889) p. 223.

rods of micaceous ilmenite, and a grain of apatite are the accessory minerals.

In this place may be mentioned a thin bed of limestone which occurs on the eastern side of the Rocky Valley, and is traceable elsewhere at the same horizon as a greyish-white compact rock, with a very slabby fracture produced by the presence of mica-scales. This rock and its varieties effervesce energetically with hydrochloric acid in the cold. Thin sections show the rocks to consist of calcite, with a few quartz-grains, flakes of tourmaline, and sericitic mica as accessories. Dr. G. J. Hinde, F.R.S., who has kindly looked at one slide, tells me that it contains echinoderm-fragments.

This limestone-bed occurs at the base of, and is inseparable from, the Volcanic Series, so that in some instances the members of the latter may have been extruded as lavas or deposited as tuffs under conditions which were suitable for the formation of a limestone.

In the rocks now to be described carbonates are conspicuous, and appear to be in part the infilling of vesicles.

Scattered apparently fortuitously among the other members of the Volcanic Series, these rocks are distinguished by the presence of calcite and a yellowish-green mica, the former often concentrated in bands. On the coast, the upper part of the cliff on the western side of Bossiney Haven and the lower part of Smith's Cliff provide excellent sections; and, inland, scattered outcrops appear at Tregrylls, Tremail, Treglasta, Trevènn, and elsewhere.

The rock at Bossiney Haven contains irregular lenticles of calcite, about $\cdot 5 \times \cdot 15$ of an inch in size, which pass abruptly into the surrounding rock (fig. 3, p. 418). A greenish mica and some crystals of epidote are conspicuous on foliation-surfaces, the individual flakes of the former being just discernible to the naked eye, while the crystals of the latter attain a tenth of an inch in length.

Carbonates are conspicuous in a thin section, the grains being arranged in irregular ellipses, up to ·15 inch in length, bordered and penetrated by well-formed flakes of yellowish-green mica. The latter mineral also commonly forms lenticular patches, in which many crystals have grown transversely to the foliation. Locally they are studded with sphene. Doubtless the colourless crypto-crystalline groundmass in which these lenticles of calcite lie represents 'in a general way the felspathic constituent of the original rock,' as in the most metamorphosed of the basic lavas, described by Messrs. Harker & Marr[1] from the neighbourhood of the Shap Granite. This groundmass is spotted with crystals of epidote, flakes and grains of opacite, magnetite, and ilmenite, granules of sphene and rutile, and innumerable minute specks of mica. Earlier in formation than the large mica-flakes above mentioned, but associated with them, are the faintly-pleochroic crystals of epidote,[2] most

[1] Quart. Journ. Geol. Soc. vol. xlix (1893) p. 362.

[2] For a description of the epidote in this rock, see W. M. Hutchings, Geol. Mag. 1889, p. 105.

conspicuously idiomorphic when surrounded by the former mineral. Conspicuous also are rounded nodules of quartz-grains, spangled with minute specks of mica and calcite, recalling amygdaloids by their shape, though some may have been produced by the alteration and replacement of a felspar. The last-named mineral occurs in recognizable form, twinned and of low extinction-angles, sometimes a twentieth of an inch across. The carbonates of the lenticles are associated with grains of quartz in such a connection as might be produced by corrosion. The quartz forms rounded grains, sometimes embaying the carbonate-granules in blunt tongues, at others

Fig. 3.—*Rock from Bossiney Haven*, $\times 45$.

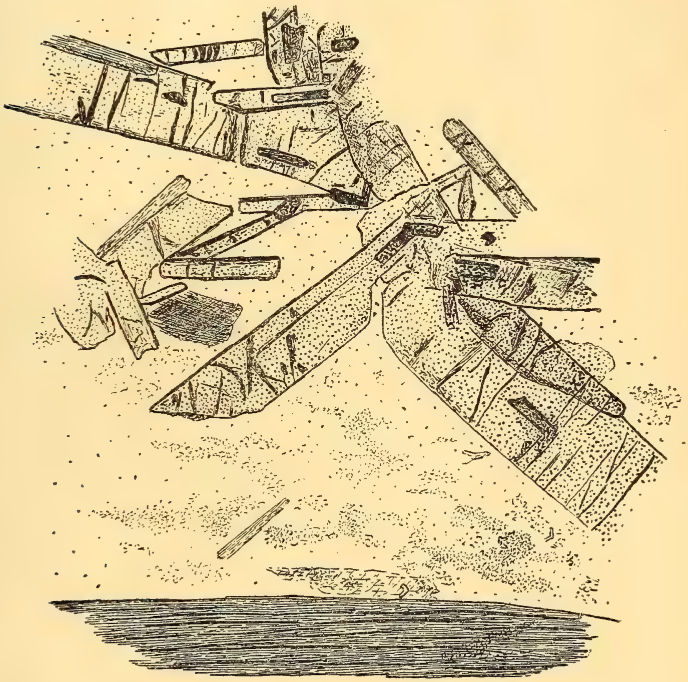
[Part of a lenticular aggregate of calcite (dotted) and quartz, surrounded by the reconstructed groundmass, containing specks of iron-oxides, mica-flakes, etc. Biotite (*b*) is conspicuous, frequently associated with epidote (*e*).]

enclosing particles within its substance. These globular particles are not infrequently attached to an adjacent grain of calcite or dolomite, as though the process of isolation were incomplete. Resembling the quartz in habit and appearance are grains of a translucent felspar, agreeing in extinction with albite.

A thin section of the rock from Bossiney Haven, cut parallel to the foliation and through one of the less calcareous laminæ, shows a plexus of very elongated crystals of epidote embedded in a uniform

grass-green chlorite, without visible structure, in which lie also partly-altered plates of brown mica (fig. 4). A considerable proportion of the slice (including some of the epidote-crystals) is rendered opaque by dust of magnetite, specular iron, etc. associated with granules of sphene and groups of rutile-prisms. In some slides the latter mineral occurs in quantity.[1] The rutile appears to have been,

Fig. 4.—*Crystals of epidote (enclosing allanite) and biotite contained in a chloritic 'base,' ×40. From Bossiney Haven.*



[The section is cut parallel to the foliation.]

on the whole, the first mineral to form, and was followed by magnetite and sphene. Epidote preceded biotite. Probably there was but little difference in the times of formation of the first three minerals.[2]

The initial steps in the production of epidote are shown in a rock from Trambley Cove which seems originally to have been a diabase, and in which an approximation may still be made to the several areas originally occupied by the augite and felspar. Parts of the slice are dappled with flakes of green mica, often vaguely outlined,

[1] See W. M. Hutchings, Geol. Mag. 1889, p. 104.
[2] See A. Harker & J. E. Marr, Quart. Journ. Geol. Soc. vol. xlix (1893) p. 364.

but not rarely in well-built crystals which have formed in many instances across the foliation. These, no doubt, are the alteration-products of the primary ferromagnesian constituent, and are locally associated with clouds of magnetite-granules. Among these mica-flakes, and also in the originally more felspathic part of the rock, are long crystals of colourless epidote, connected with a considerable quantity of carbonate and a mosaic of translucent grains, partly representing the original felspar.

In such a rock a considerable transference of material must have taken place; in that from Bossiney Haven the complete reconstruction has been accomplished, and I conclude that we have to deal with basic rocks of the composition of a diabase or diabase-tuff in which the lime of the felspar, together with part of its alumina, has gone towards the making of the epidote, while the remainder of the alumina, together with that which the augite may have contained *plus* its magnesia and iron, have aided in producing the biotite. Rutile, magnetite, and sphene arose from the reconstitution of the ilmenite.

Study of several slides suggests the following sequence of events as comprising the history of these rocks:—

Reconstruction—aided perhaps by contact—produced first epidote and then green biotite, and was followed by pressure. The epidote and the quartz were saved by the yielding of the carbonates, chlorite, and biotite (a result dependent on the proportion of hard to soft minerals). On the cessation of the pressure the calcite was reconstructed; but since there is evident corrosion of the epidote and biotite by both calcite and quartz, I infer an introduction of additional mineral matter in solution (carbonate of lime and silica); which also produced the intimate association of the quartz and carbonates above recorded, and which was attended possibly by a revival of crystallization in other minerals than calcite.

The late introduction of extraneous material is supported by the following evidence. Among the rocks of Trambley Cove, which appear to be a slaty variety of the Volcanic Series, occur irregular rope-like bands, occasionally mere knots or eyes, consisting almost entirely of tourmaline. A thin section, cut transversely to the direction of the band, is composed of prisms of tourmaline lying in two planes at right angles, and packed closely together to the almost entire exclusion of interstitial material, which, when found, is quartz. The dichroism of the tourmaline is

E, pale pinkish-brown.
O, bluish-green,

The absorption is considerable.

The crystalline arrangement shows strong flexures, but the prisms are unbroken, and I am indebted to Prof. Bonney, to whom I showed the slide, for the suggestion that tourmalinization took place after the pressure, the prisms forming along the flexures so produced.

Barras Nose.—Before leaving these rocks, a brief description must be given of a peculiar crag situated on the end of Barras Nose. It is about 6 feet in height, consisting below of soft greenish 'slates' passing upward sharply into a conspicuously-banded rock. The lighter-coloured bands are composed of a granular aggregate of calcite and quartz, the former predominating, with here and there a flake of blue tourmaline; the darker, of the same constituents with, in addition, a few flakes of white mica and a very considerable quantity of magnetite, which forms at least half the bulk of the rock. These bands endure only for some 12 inches, and are succeeded by a dark-grey compact rock with a somewhat slaggy manner of weathering, which forms eyes or lenticular bands in a matrix like the lighter-coloured and softer parts of the lower crag, here, as there, plentifully sprinkled with crystals of magnetite in streaks or thin bands. Higher, we see the dark lenticular bands increasing, the lighter-coloured bands decreasing in relative importance, until the latter are observable only with difficulty. Under the microscope the grey lenticular bands resemble an altered lava of a trachytic type, permeated by calcite and dolomite which, in some places, constitute nearly half the slide. Translucent lath-shaped felspars, containing specks of carbonates and minute flakes of mica, are common. The inclusions bear a relation to structural planes. Dolomite or calcite is in process of replacing the felspar-laths, although much of the carbonate has scarcely the appearance of a pseudomorph. The slide contains much opacite and magnetite-dust. These, together with a fine cryptocrystalline mosaic, form the 'base' of the rock. Coloured minerals are conspicuously absent. The rock appears to be an altered lava, similar in its essential characters to others from the same headland, from the right bank of the Rocky Valley, and Bossiney Haven, the rocks differing merely in the relative proportions of carbonates and secondary biotite, and in the size of the felspar-laths.

The magnetite, concentrated chiefly in the lower part of the crag, weathers out from the softer limestone in prominent ridges, the individual crystals reaching occasionally ·07 inch across. In some slides they are associated with grass-green and white micas. As a rule, the magnetite is idiomorphic; while interstitially, forming smaller grains or as dust, is a little hæmatite. Nests of large dusty calcite-grains, unmixed with any of quartz, constitute the section apart from the magnetite-bands. A few small grains of blue tourmaline occur as an accessory mineral.[1]

Crushing has somewhat obscured the relation of the carbonates and the quartz, but in many instances the quartz-grains are fringed by a zone of granules of the carbonate, hinting at a practically simultaneous separation of the two.

As regards the formation of the magnetite, its idiomorphic outlines and habit of occurring in groups of grains militate against

[1] It is of interest to note that the tourmaline may be embedded in the magnetite (rarely also a flake of green mica). These tourmalines are exceedingly small, often as little as ·0006 inch in prism-diameter.

a detrital origin; in other words, it has doubtless formed in place. Probably the quartz and carbonates were deposited by water, the corrosion of the calcite indicating that, of the two, the water charged with silica was the later. The presence of tourmaline also points to hydrothermal agents. Possibly the magnetite was leached out of a rock similar to that which constitutes the 'lenticles,' and concentrated elsewhere, crystallizing as it was deposited.

That iron is present in some quantity in the neighbourhood is shown by a thin section cut from a slaty-looking rock found some 2 yards away. Here we have some fairly well-formed crystals of magnetite, while the slide is thickly (though irregularly) powdered with dust of the same mineral, possibly specular iron, and some ilmenite. The rest of the rock consists of green chlorite, very inert with either or both of the nicols; quartz; disseminated carbonates, associated often with the quartz; and some flakes of mica. A few small and dusty grains may possibly represent a felspar. The rock is conceivably a highly decomposed and altered diabase or dolerite.

Two specimens underlying the limestone-band above described, between the east side of the Rocky Valley and Trewethet Gut, exemplify the passage of the Volcanic Series into the Lower Blue-Black Slates.

The first is a dull greenish-grey rock, spangled with bronze-coloured plates of mica and speckled with minute black crystals. On surfaces at right angles to the foliation calcite can be discerned. In a thin section the dusty crystals of this mineral are conspicuous, and are arranged, as in previous examples, in lenticular patches resembling amygdaloids. Much indefinite, or, rather fibrous grey material makes up the rest of the section, together with small subangular grains of quartz and carbonates, films of white mica, and larger crystals of a green variety of the last-named mineral. The rock gives some evidence of crush followed by a revival in crystallization of the green mica.

The second specimen is much more slate-like in appearance. In colour it is bluish-grey with rusty spots, sufficiently soft to be marked by the nail, and containing stumpy crystals of a black mineral. Carbonates are absent, and the slide shows a rough banding, parts composed of chloritic or micaceous films alternating with gritty layers. Intertwined with the subangular quartz-grains of the latter are small flakes of greenish mica, averaging ·0012 inch in length. The black crystals of the hand-specimen are crystals of mica larger than those mentioned, green in colour through alteration and formed *in situ*, commonly athwart the foliation. The largest included in the section is ·05 inch in length. Hæmatite (probably) forming irregular grains, possibly a little specular iron, and locally rusty staining represent the iron-minerals.

The Hallwell-Cottage Beds.

Microscopically the Hallwell-Cottage Beds consist of closely-interwoven flakes of sericite, in which unorientated crystals (brightly polarizing) are thickly scattered.

The darker bands are produced by the presence of a feebly dichroic and inert chlorite, which forms an irregular network in which lie crystals of clinochlore. This mineral occurs in lath-shaped crystals with ragged terminations, plentifully besprinkled with inclusions which are usually arranged along the central part, but not sufficiently to obscure the characters of the mineral. Many of the enclosures are minute prisms and granules, resembling rutile. Cleavage is not conspicuous, and polysynthetic twinning is usual[1] (fig. 5). The extinction-angle between twins is about 12°. The colour for vibrations parallel to the basal plane is grass-green; at right angles to this pale yellowish-green. The largest crystals measure about ·045 inch in length. The mineral is distinguished from ottrelite, which it resembles, by its softness, lower specific gravity, and lower refractive index. Mr. Maynard Hutchings has kindly forwarded to me his sections of ottrelite-phyllite from near Trevena Church, and I find the two minerals to be perfectly distinct. The rocks invariably contain hæmatite or some other iron-oxide. In a field-quarry near Davidstow Vicarage the rock is banded with arenaceous laminæ, a character common in the beds of the group. A thin section shows that prisms of rutile occur in the clinochlore and in the body of the rock. Some quantity of an opaque granular mineral, probably hæmatite, and dusty-brown matter are scattered through the slide.

Fig. 5.—*Phyllite containing clinochlore, ×40. Western end of Trewassa, near Davidstow.*

The Hallwell-Cottage Beds from other localities (as, for example, Doney's Shop and Rosebenault, not far from St. Clether; and Benoath Cove near Bossiney Haven) differ, but in minor details, from those of Trewassa. Clinochlore characterizes the more typical rocks, favouring

[1] See A. Renard, Bull. Mus. Roy. Hist. Nat. Belg. vol. iii (1884–85) pp. 250 *et seqq.*; J. S. Flett, 'The Geology of Lower Strathspey' Mem. Geol. Surv. Expl. of Sheet 85 (1902) pp. 48–49.

the micaceous bands. These are often stained by a yellowish pigment, which may possibly be of organic origin. In the lighter-coloured bands the mica-flakes are sufficiently large to be individualized, and are associated with small grains of quartz,[1] and possibly of secondary felspar. These rocks, therefore, consisted of argillaceous alternating with more arenaceous laminæ, in which, through the agencies of heat and pressure, mica has been extensively developed.

Hæmatite and other iron-oxides characterize all the slides, sometimes at least favouring certain bands in the rocks. Zircon, rutile, and probably a little tourmaline are accessory minerals.

Rusty-black bands, harder and darker than the silvery-grey soft rock with which they are associated, are found in the railway-cutting south of Hendraburnick, on the main road south of the Rocky Valley, and elsewhere. A slight silvery sheen characterizes the foliation-surfaces, athwart this direction a fibrous appearance, the larger crystals being visible to the unaided eye. A thin section shows the rock to consist of white mica-flakes, embedded in a matrix of essentially the same composition, but in which the crystals are too small and too closely entangled to be separated. A few grains of hæmatite and a large number of orientated rods of micaceous ilmenite[2] are scattered all over the slide. Quartz is practically absent, tourmaline a rare accessory, and clinochlore occurs locally. Numerous particles scattered through the slice are too small for determination, but doubtless many are rutile.

A thinly-bedded silvery to iron-grey phyllite, sufficiently soft to be marked by the nail, and locally banded, which occurs at Trevivian Farm, represents a common type in which clinochlore is absent. It consists of closely-interwoven flakes of sericite, many of which can be individualized between crossed nicols (·005 inch in length). Doubtless some chlorite is also present; and the slide is thickly sprinkled with jagged grains of hæmatite roughly averaging ·001 inch across; the brownish dust appearing under a high power over a great part of the slice is possibly the same mineral.

Multitudes of minute prisms of rutile[3] occur in the 'base' of this rock, and in varying degree in many of the preceding slides.

In this type of rock without clinochlore minor variations occur in the size of the flakes of white mica, the proportion of feebly-polarizing chloritic scales, and the size and shape of the granules of iron-oxide.

The Penpethy Beds.

Excellent sections of these rocks are found on either side of the

[1] These rocks rather strongly recall the spilosites and desmosites of the Harz. See J. J. H. Teall's 'British Petrography' 1888, p. 218, and references there given; also A. Renard, Bull. Mus. Roy. Hist. Nat. Belg. vol. iii (1884–85) p. 233.

[2] Recorded by Mr. W. M. Hutchings, Geol. Mag. 1889, p. 217. For description and figure, see A. Renard, Bull. Mus. Roy. Hist. Nat. Belg. vol. iii (1884–85) p. 258 & pl. xiii, fig. 1.

[3] Recorded also by Mr. W. M. Hutchings, Geol. Mag. 1889, p. 220.

road leading from Camelford Station to Trebarwith Strand in the neighbourhood of Penpethy (1-inch map).

In the Prince of Wales's Quarry the dark phyllites split readily into thin slabs, with a silvery lustre on their foliation-surfaces. They are rather harder than the nail. The rocks consist of minute scales of a green chlorite lying in a colourless 'base.' The latter frequently frees itself from the less translucent mineral, producing a mottled aspect in the slide. Minute flakes of white mica can be detected by means of their higher polarization. Specks of iron-oxides (hæmatite and ilmenite) are important constituents, and rutile, zircon, and tourmaline [1] are not uncommon.

In many instances the last-named has exceptionally perfect crystal-faces. Elongated fibrous crystals of a brown colour, not pleochroic and with no effect on polarized light, are common, and appear to be authigenous. They are often surrounded by a fringe of chlorite.

Microscopically the rock of Condolden Quarry (between Penpethy and Waterpit Down) is identical with that of Higher Pendavey Quarry described below.

A grey grit occurs to the west of Lower Penpethy, composed of a mosaic of quartz-grains—subangular and interlocking, no doubt through secondary additions—in which lie flakes of green mica and sericite. I have noticed no felspar-remnants. Since the micas are clearly not detrital, the rock provides evidence of a considerable reconstruction. Flakes of ilmenite are a common accessory, and some of hæmatite.

The Slaughterbridge Beds.

The rocks of this group are black or bluish to greyish-black phyllites, locally greatly crushed, and in some places altered as though by contact-metamorphism, as, for instance, in the cutting south of Villaparks and on Griggs' Down. In the majority of thin sections of the dark phyllites collected near Trekeek, Villaparks, and Slaughterbridge, a close resemblance can be traced to some member of one of the overlying series; that is, these rocks possess no very definite characteristic of their own.

In the phyllites from Villaparks, Higher Pendavey, and around Slaughterbridge, minute fibres of a greenish chlorite, intermingled with a variable quantity of white mica, constitute the major portion of the slides. Through this groundmass larger stumpy crystals of white mica and rods of micaceous ilmenite are scattered. At Villaparks, as to the north of Tregrylls, white spots characterize the hand-specimens, but are often ground-out in thin slices.

In the quarry at Griggs' Down, Davidstow Moor, a phyllite is found, closely resembling in its general structure the rocks around Slaughterbridge, in that it consists of a closely-knit intergrowth of minute flakes of chlorite and mica, through which are scattered

[1] See A. Renard, Bull. Mus. Roy. Hist. Nat. Belg. vol. ii (1883) p. 132. The form of the tourmaline-crystals from Penpethy is the same as that which the late Prof. Renard described.

larger flakes of the last-named mineral. Evidence of contact-metamorphism is, however, shown by the presence of shadowy patches, rather more opaque than their surroundings, and producing little effect between the two nicols. Associated with these spots are numerous much smaller ones [1] of an orange-yellow colour, which exhibit no definite microscopical characters, and do not appear distinctly marked off from the larger spots when they are included by them. There can be little doubt that these represent incipient staurolite.

By the stream-side near Higher Trefrew (north of the word Slaughterbridge on the 1-inch map) a greatly-crushed rock of igneous origin has been worked in a few shallow pits, but as it is surrounded by moorland its relation to the slates has not been made out. A thin section shows the remnants of felspar, secondary biotite, flakes of a green mica, and a mosaic of crushed quartz and felspar. The biotite is of a rich brown, aggregated patchily in groups, members of which were occasionally strong enough to form boldly across the foliation. The mineral suggests by its appearance that it underwent pressure, which was followed by some mineral revival. The original rock, whether pyroclastic or not, was of an acid composition.

The Upper and Lower Blue-Black Slates.

These may be subdivided into two types. The first are soft and not banded; in the second well-marked laminæ are conspicuous, and the rocks are sufficiently hard to resist a knife-blade. Both apparently contain carbonaceous particles. The second type occurs characteristically above the Volcanic Series, but the first are found on that horizon at Tregulland, at Davidstow, in cutting No. 90 of the London & South-Western Railway, and elsewhere. The brittle rocks of the second type consist almost entirely of subangular or irregular quartz-grains [2]; these form a fine mosaic, through which are scattered carbonaceous particles and minute flakes of greenish-white mica. Although in a different crystalline condition, these rocks recall some of the radiolarian cherts from the Lower Culm.[3]

The Greenstones (Epidiorites).

In a small pit near Stone Cross, west of St. Clether, is quarried a peculiar rock which answers to the 'epidiorites' of Gümbel. Augite is entirely absent, the ferromagnesian constituent is an actinolitic hornblende, the crystals of which are arranged in clumps and tufts. The felspar shows no definite structure, but is, on the contrary, blotched by clouds of kaolin, and between crossed nicols is cryptocrystalline. Large patches of ilmenite—usually replaced by

[1] Averaging ·002 inch across; the larger patches are about ·015 inch in length.

[2] Referred to by Mr. W. M. Hutchings as 'very fine-grained quartzites,' Geol. Mag. 1889, p. 220.

[3] For an opportunity of examining a large number of sections of these rocks I am indebted to the kindness of Mr. Howard Fox, F.G.S.

leucoxene and associated with a little sphene—apatite, and chlorite, are the remaining minerals.

In the rock from the field to the east of King Arthur's Hotel, Tintagel, the hornblende forms large plates doubtless replacing augite. The felspar is converted into an aggregate of decomposition-products, but appears to have crystallized before the original augite. Epidote is common, and impure granular sphene is present in quantity (ilmenite is absent).

Conclusions.

The contents of the preceding pages may be embodied in the following conclusions :—

1. That from St. Clether, as far as the coast south of Boscastle, the Upper Devonian Beds (with *Spirifera Verneuilii*) have a fairly uniform strike from east-south-east to west-north-west, with a northerly dip; but that along the coast in a southerly direction, from the Rocky Valley to Trebarwith Strand, the higher beds again appear, a result attained partly by north-north-easterly faults, partly by an alteration of strike (see p. 409).

2. That, the beds having acquired their present dip, subsequent pressure resulted in great brecciation and contortion of the harder strata, and in a general though less obvious compression of the softer members: such pressure being locally relieved by differential movement parallel to the dip (see pp. 409, 410).

3. That the most distinctive rocks of the district are a series of ashes and basic lavas, usually greatly altered, and not infrequently entirely reconstructed, with the development of chlorite, white mica, actinolite, sphene, epidote, allanite, etc.; and that these were deposited, at least in part, in a sea in which limestone was forming (p. 417). These are called the 'Volcanic Series' (pp. 411 & 414).

4. That, with the exception of intrusive epidiorites,[1] the remaining rocks of the district are sedimentary, and closely resemble the phyllites of the Ardennes described by the late Prof. Renard.

5. That these phyllites are distinguished by petrographical features according to which they may be subdivided.

These subdivisions are :—Comparatively thin beds of Blue-Black Slates—including quartzose beds—above and below the Volcanic Series; the uppermost of these overlain by soft greenish-grey or dark-grey phyllites containing a mineral resembling orthoclase in the western part of the district; the lower underlain, in descending sequence, (*a*) by banded phyllites, locally quartzose and containing clinochlore (Hallwell-Cottage Beds); (*b*) by soft silvery-grey phyllites, locally harder and darker, and sufficiently cleaved to be used for slates, occasionally with quartzose bands (Penpethy Beds): and (*c*) by black, bluish, or greyish-black phyllites, locally containing various contact-minerals (Slaughterbridge Beds).

[1] I except here also the rock described on p. 426 from Higher Trefrew, and igneous rocks which occur locally above and below the Volcanic Series, as near Tintagel.

EXPLANATION OF PLATE XXV.

Geological map of the Tintagel and Davidstow District, on the scale ot 1 inch to the mile.

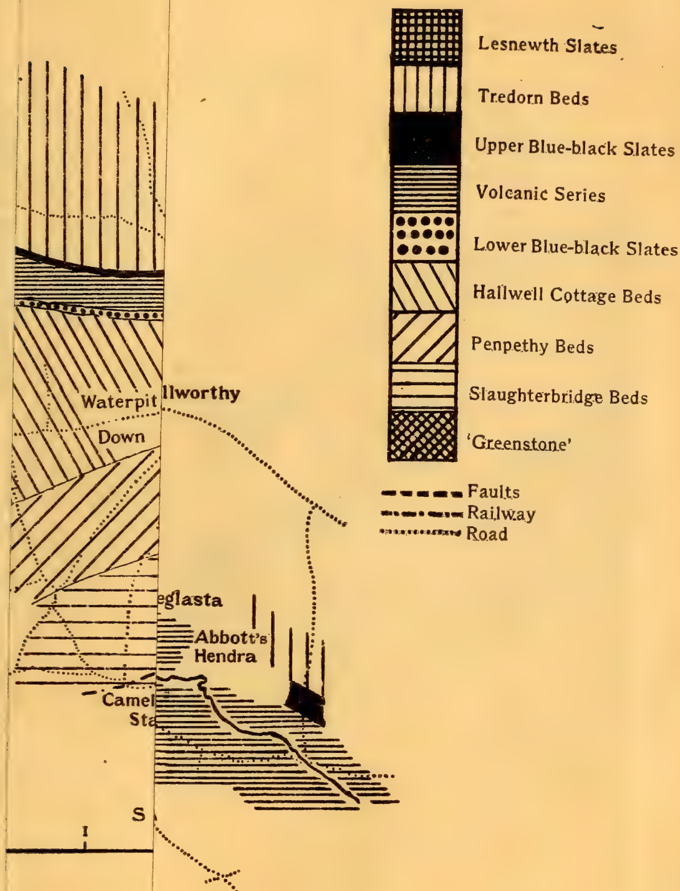
Discussion.

Prof. Bonney expressed his sense of the value of the paper, upon which he knew that the Author had expended great pains, for he had seen the work at more than one stage in its progress. He quite agreed that there was evidence of pressure and in some parts of contact-metamorphism, although no granite was seen above ground. He had thought that the obscure white spots were probably a secondary felspar, and enquired whether the mineral named 'clinochlore' might not be ottrelite.

Mr. H. H. Thomas congratulated the Author on his discovery of staurolite in the metamorphosed sediments; although this mineral was by no means rare in other similar localities, it had (to the speaker's knowledge) only once before been mentioned from either Devon or Cornwall. The occurrence had been noted by the late R. N. Worth, in Devon. This was therefore an interesting addition to the list of Cornish metamorphic minerals.

Mr. Teall said that the subdivision of the great Killas formation of Cornwall was attended with considerable difficulty, in consequence of the general absence, over large areas, of any sharply-defined lithological horizons. The re-survey which was now in progress was approaching the area in question, and he had no doubt that the Author's detailed mapping, coupled as it was with careful descriptions of the rocks, would prove to be of considerable service. He was glad that the Author had preceded the Geological Survey, and had found at least one group of most interesting rocks which could be mapped with comparative ease.

The Author, after thanking the Fellows for the kind manner in which the paper had been received, said, in reply to a question from the President, that the only *indubitable* instances of contact-metamorphism were from the south-eastern part of the district; but that, if contact were not responsible for the changes wrought in the Volcanic Series, he was at a loss to assign a cause. These changes were at least as great on the coast as in the inland part of the district. So far as he knew, the metamorphism was unlike that of rocks as yet described from other parts of Cornwall or from Devon; it recalled, however, in one or two instances the schists of the Start district. In reply to Prof. Bonney's question, concerning the distinction between the clinochlore shown on the screen and ottrelite, he said that the former mineral was softer, had a lower specific gravity, and also lacked the bluish element in the pleochroism. Commenting on Mr. Teall's remark as to the usefulness of the Volcanic Series for mapping, the Author stated that he thought it probable that these rocks were continued south-westward, but that he believed that their metamorphic character was not maintained.


Lesnewth Slates
Tredorn Beds
Upper Blue-black Slates
Volcanic Series
Lower Blue-black Slates
Hallwell Cottage Beds
Penpethy Beds
Slaughterbridge Beds
'Greenstone'
Faults
Railway
Road
Waterpit
Down
llworthy
eglasta
Abbott's
Hendra
Camel
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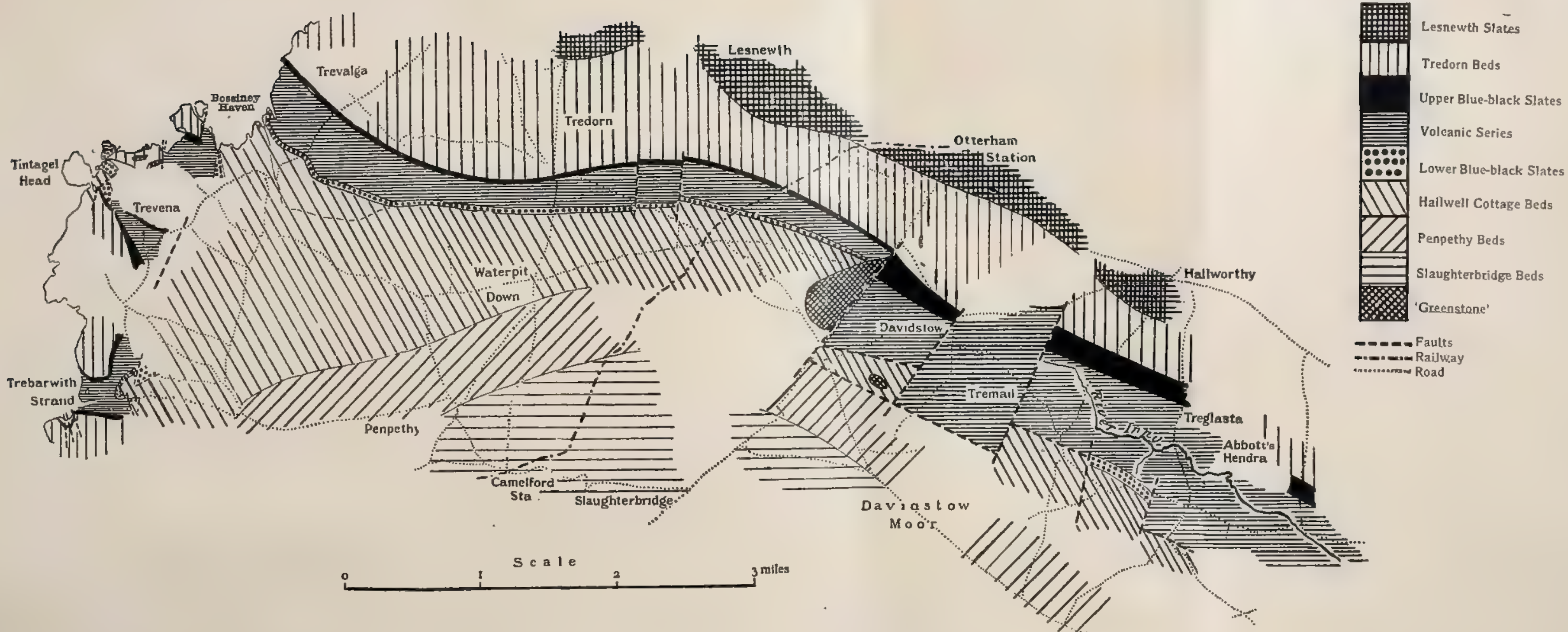


Geological Map of the Tintagel and Davidstow District.

35. *On* Primary *and* Secondary Devitrification *in* Glassy Igneous Rocks. By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S., and John Parkinson, Esq., B.A., F.G.S. (Read June 10th, 1903.)

[Plate XXVI.]

A few prefatory words are needed in explanation of the form of this paper. The authors have frequently discussed its subject, the elder of them having kept it in view since 1877[1]; while the younger has enjoyed favourable opportunities of studying large spherulites, especially those in the obsidian of the Yellowstone, which the other knows only from hand-specimens. When they had agreed upon a joint paper, each wrote a draft, one of them having undertaken to fuse them together. But he found this impracticable; for, while their conclusions were practically identical, the paths followed were very different, so the papers, after substituting cross-references for some passages common to both, are now presented as separate chapters.

Part I.—By John Parkinson, Esq., B.A., F.G.S.

The excellent account and figures published in the Memoirs of the United States Geological Survey by Prof. J. P. Iddings[2] render superfluous any general description of the well-known spherulites of Obsidian Cliff in the Yellowstone Park. Nevertheless some mention, however brief, must be made of a few facts, as these are closely connected with the general problem of devitrification.

Excluding microliths, the first-formed crystallizations are the 'granophyre-groups' of Prof. Iddings. These are intergrowths of felspar and quartz built with extreme delicacy, two or more crystals of felspar entering into the composition and forming rectangular or rudely spherical outlines. The greater the number of felspar-individuals the closer is the approximation obtained to a spherical form. As Prof. Iddings states, it is clear that these microscopic 'granophyre-groups,' together with the trichites and microliths, formed before the lava came to rest.

Crystallizations apparently of this type appear in most thin sections of the obsidian, but their fibrous structure is barely capable of resolution into components. The fibres are directed at right angles to the containing surfaces. Crystallization then proceeded on the more strictly spherulitic plan. According to Prof. Iddings the first of this type to form were minute colourless spheres, 'their finely-fibrous structure' made evident only by the employment of 'highly-converging light.'

[1] See his paper 'On certain Rock-Structures, as illustrated by Pitchstones & Felsites in Arran' Geol. Mag. 1877, p. 499.

[2] 7th Ann. Rep. U.S. Geol. Surv. (1885–86) pp. 249–95 & pls. ix–xviii; see also Monogr. U.S. Geol. Surv. vol. xxxii (1899) pt. ii.

The second product of spherulitic crystallization was the larger variety, blue in a hand-specimen, but brown by transmitted light in a thin section. Mention is made of the fact that the fibres which form these spherulites 'are in sectors and do not radiate from a single point,' and from the resemblance 'in structure and optical behaviour' to the 'fibrous granophyre-groups,' the inference is drawn that the composition is essentially the same.

Finally, a description is given of the characteristic 'porous spherulites.' An account recently published[1] renders additional notice unnecessary at this point.

The foregoing order of crystallization affords a simple basis for classification.

In the first place the minute colourless spheres, often, or indeed usually surrounded by a crack which forms a boundary, appear to have been produced as a result of strains set up in the cooling rock, as Mr. Rutley has described.[2] Frequently a microlith forms a central nucleus. When these spherulites lie within the fibrous brown type no boundary-crack is visible, nor does the latter, in any case, necessarily surround the spherulite completely.

The fact is noteworthy that the formation of the fibrous brown spherulites has not disturbed the orientation of the black microliths, whereas in the small colourless spheres they lie tangentially.

It is of interest to find that perlitic cracks may appear in the neighbourhood of the small colourless spherulites, unconnected with any sign of radial growth; hence we may infer that the spherulites were antecedent rather than subsequent to the formation of the cracks, and may indeed have caused them as above suggested. Occasionally, an additional crack appears concentric with, but entirely external to, the spherulite. Here then the latter appears to be the earlier structure. On the other hand, if this suggestion of strain is true, it is not easy to understand why such isolated areas should occur in the midst of the fibrous brown spherulites.

The finely-fibrous structure which Prof. Iddings records suggests mineral differentiation, rather than mere strain in a homogeneous substance.

Under a second heading may be placed the compact and fibrous brown spherulites which occur, not merely at Obsidian Cliff, but in the devitrified rocks of Pontesford, Wrockwardine, Boulay Bay, and the Prescelley Hills. It is of interest to note that in these examples—pre-Cambrian and Palæozoic—the matrix in which the spherulites lie affords clear evidence, by the abundance of its perlitic cracks, that it solidified as a glass. This type of spherulite would appear to form a criterion of secondary devitrification in the adjoining matrix.

The 'porous spherulites' constitute a third subdivision. Little remains to add to what has been already written regarding

[1] Quart. Journ. Geol. Soc. vol. lvii (1901) p. 211.
[2] *Ibid.* vol. xxxvii (1881) p. 396.

them; except to call attention to the peculiar feathery crystals, especially characterizing those patches of the rock in which a radial growth is inconspicuous. When most perfectly developed, this peculiar structure is but a large variety of the branching rods of felspar of which a good figure is given in pl. xvii, fig. 2, of the 7th Ann. Rep. U.S. Geol. Surv. (1885–86).

In the type under consideration the rods are broader, in comparison with their length, than those figured; and, while more curved in outline, exhibit branches which are more stumpy and less conspicuous (Pl. XXVI, fig. 1). Although this mineral is often free from the scattered black microliths, yet not uncommonly an example is crossed by regularly-spaced rows of these earliest of crystallizations, frequently arranged with a slight outward convexity, suggesting a forward pushing of foreign substances, which, finally, were perforce engulfed. Often, when most irregular in outline, these crystallizations are composite, breaking up into a granular mosaic as the stage is slowly turned, extinction proceeding in consecutive and regular jerks from grain to grain for the entire length or width of the area under consideration. I regard this as implying that the molecules of the various component grains are orientated in nearly similar directions, each being surrounded by a zone of doubtful polarization in which the change takes place from the direction of orientation of the molecules of one grain to that adopted by the molecules of the adjacent grain. Flow-structure often complicates the crystallization of the rock. A comparatively-coarse translucent mineral—no doubt usually tridymite—commonly enters largely into the composition, while in an occasional instance of the 'granophyre-groups,' the black microlith and a confused mass of small spherulites form the rest of the field. The 'feathery growth' appears locally, and constitutes a semispherulitic patch or an entire band in the rock. As in other spherulites, a slight line of discontinuity apparently favours growth.

As regards the origin of these 'feathers,' their occurrence in the 'porous patches' associated with tridymite forcibly suggests a connection with superheated steam. Their shape curiously resembles the frosting of glass or pavements; and their similarity to the branching felspar-rods, figured by Prof. Iddings, suggests a community of origin. We both consider the structure as a result of resistance to growth, and it is discussed at greater length in Prof. Bonney's part of this paper.

Conditions which favoured Primary Devitrification at Obsidian Cliff.

The fact that the spherulites formed in far greater proportion in the upper part of the lava-flow which now makes Obsidian Cliff, points to a low pressure with active water-content, an initially-high temperature and rapid fall, as being physical conditions requisite to their production. This disposition of the spherulites, among which the hollow variety is conspicuous, is very marked in looking at the exposure as a whole, especially as the columnar

structure which characterizes the lower compact obsidian fades away in the upper scoriaceous layer.

Since an eutectic favours crystallization, the inference is clear that, either obsidian-glass is not an eutectic, or is an eutectic of soda-felspar (albite or oligoclase), potash-felspar, quartz, and water suddenly cooled.

Specimens taken from the lowest part of the cliff and from the centre of the columns, where it is safe to assume that cooling proceeded most slowly, show no sign of primary devitrification in a thin section. Moreover, it must be exceedingly rare for a magma devoid of porphyritic crystals (which might utilize constituents in excess) to possess eutectic proportions. Hence we may conclude that the latter condition did not obtain.

Types of Primary Devitrification.

The types of primary devitrification and the causes which govern their formation are discussed by Prof. Bonney in Part II of this paper, so that one or two special examples are all that need be mentioned at this stage.

In two slides, I believe that I detect an arrangement of minerals which suggests that an eutectic zone may follow the crystallization of an overplus of quartz.[1] In one case the main part of the rock consists of secondarily-devitrified glass; in the other ('porphyry-pitchstone' from Spechthausen) it is composed of small spherulites, and here the so-called 'eutectic zone' has a spherulitic appearance, differing from the surrounding material merely in being slightly coarser.

In this slide the 'eutectic' structure usually forms isolated patches, or a band, of more or less micrographic material, in which either quartz or felspar may predominate, surrounded by a more homogeneous matrix. In a third instance, from Anne Port (Jersey), the structure closely resembles an illustration given by Mr. J. E. Stead[2] which shows three contiguous grains of a metal-ingot containing 1·8 per cent. of phosphorus. A triangular patch of eutectic occurs in the space between the three grains. In the Anne-Port slide the resemblance is heightened by the body of the rock, which surrounds the semi-micrographic patch, breaking up between crossed nicols into the mosaic of grains (referred to on a later page as 'patchy devitrification') which simulate the components forming the grains of the ingot.

Another instance from the same island (south of Vicart Cliffs) presents similar structures (Pl. XXVI. fig. 2). In this the early crystallization of the superfluous silica is well shown, bordered by an intergrowth of quartz and felspar, crystals of the latter projecting into the central grain or group of grains. In the body of the rock the differentiation of the constituents is barely perceptible,

[1] That is, a zone with a micrographic arrangement of parts, in this instance not strictly marked off either from the quartz on the one hand, or from the outer rock on the other.

[2] Journ. Iron & Steel Inst. vol. lviii (1900) pl. iii, no. 2.

and between crossed nicols it breaks up into the 'patchy' type of devitrification.[1]

In one or two slides (Bonne-Nuit Bay and Anne Port, Jersey) a spherulitic structure is more or less perfectly developed, and the spherulites are surrounded by the minute quartz-felspar intergrowth. In the slice cut from the Bonne-Nuit Bay specimen the spherulitic portion is barely perceptible. Both slices exhibit patchy devitrification.

In a paper on the 'Microchemistry of Cementation' by Prof. J. O. Arnold, in the Journal of the Iron & Steel Institute,[2] a number of plates are given showing close analogies to sundry rock-structures. Two of these figures are of supersaturated steel in which the surplus cementite occurs either as 'heavy streaks' having a tendency to form regular meshes, or in well-laminated patches. The groundmass of the bar consists of 'normal pearlite.'[3] The irregular streaks mentioned bear a close resemblance to the streaked or gnarled structure of such rhyolites and obsidians as those figured by Mr. Rutley in the Quarterly Journal of this Society in 1881.[4]

Secondary Devitrification.

The rock-structures produced by secondary devitrification may be arranged under two heads:—

(*a*) Those produced solely by such crystallization, and
(*b*) Those in which secondary have been imposed on primary crystallizations.

(*a*)—An examination of a pitchstone from Carlitz, and study of numerous English examples in which the changes are much greater, suggest that secondary devitrification begins by hydration of the glass in the neighbourhood of perlitic cracks.[5]

The latter, outlined by a belt of greenish altered glass, are familiar in most devitrified perlites. In addition, in some Hungarian examples a feeble granulation can be faintly discerned between crossed nicols, favouring the neighbourhood of perlitic cracks in its distribution. The presence of water in the perlitic cracks has, no doubt, been an active agent in producing the devitrification.

Evidence that the glass was not homogeneous when it solidified may be found in the variable proportions of the green hydrated material, the dusty grains of felspar, and the clearer grains of quartz. Small variations in the amount of the dusty substance (kaolin) do not appear to affect the perfection of the granular mosaic; if,

[1] Where such separation is apparent, it would seem that the body of the rock solidified as a fine-grained eutectic, the time possibly being insufficient for coarser structures to form.

[2] Vol. liv (1898) p. 185, pls. xiii, xiv, xvii, & xix. The last two are those above referred to.

[3] *Op. cit.* p. 190. Cementite is a definite carbide of iron, Fe_3C. Pearlite is an eutectic mixture of ferrite (that is, of particles of nearly or quite pure metallic iron) and cementite, the two being usually interlaminated. Pearlite forms in slowly-cooled steels. See Ency. Brit. 9th ed. vol. xxix, p. 572.

[4] Vol. xxxvii, pp. 406 & 407.

[5] [On this point I feel uncertain.—T. G. B.]

however, it is present in such quantity as to render the slice almost opaque at that point, the grains tend to lose distinctness of outline.

(*b*)—Those in which secondary structures have been superposed on primary.

Of these the most familiar example is the irregular mosaic of grains—referred to as 'patchy devitrification.'[1]

The patches which become apparent between crossed nicols appear to be formed by the crystallization, or recrystallization, of a residual mineral. In the case of a spherulite, this is the substance left over after the recrystallization of the radial fibres of felspar. The stresses which acted on the rock before solidification affect it after solidification; for the 'patches' are elongated, radially in the case of a spherulite, parallel to the direction of flow in a rhyolite showing marked fluxion-structure. In the Boulay-Bay nodules, the dimensions and definition of the 'patches' vary considerably in the same example, and at times appear better formed near the periphery.

Many of the Boulay-Bay nodules exhibit a kind of segregation, no doubt primary, which gives rise to a sponge-like network, the interspaces being occupied by more translucent areas, as apparent in ordinary light as between crossed nicols. Under the latter conditions each of these oval spaces is occupied by material with definite and uniform polarization, differing but little from an isolated individual of the more common type of 'patchy devitrification.'

In regard to the relation between the 'patchy devitrification' and the granular mosaic produced by this secondary devitrification of a perlitic rock, see Part II, p. 440, by Prof. Bonney, to whom I am greatly indebted for help and suggestions made from time to time, the results of which are embodied in the foregoing pages.

Excluding spherulites, we may make the following summary:—

Primary Structures.	Secondary Structures.
(*a*) Glass containing no primary devitrifications. Homogeneous throughout.	Granular secondary devitrification uniform over a small area (that is, over a single slide).
(*b*) Glass containing no primary devitrifications. Not homogeneous throughout.	Granular secondary devitrification not uniform over a small area. Variability in composition traceable in a single slide.
(*c*) Rhyolite containing some primary devitrifications, as, for example, bands or patches of eutectic, and crystallizations (gnarled structure and the like) representing separation of a constituent in excess; and some original glass.	Secondary structures *b* and *d* combined.
(*d*) Rhyolite not glassy in any part.	Secondary superposed on primary devitrification, of which 'patchy devitrification' is the type.

[1] For a discussion on this structure see F. R. C. Reed, Quart. Journ. Geol. Soc. vol. li (1895) p. 165. [A slightly-different explanation of this structure is offered in Part II of the present paper, p. 441.—T. G. B.]

PART II.—By Prof. T. G. BONNEY, D.Sc., LL.D., F.R.S., F.G.S.

The solidification of a mass of given chemical composition is a question of temperature, its crystallization of environment. We may regard a glass as a mixture of molecules, each endowed with polarities enabling it to join in building a crystal belonging to a particular group, but at present associated without the orientation which is essential for the existence of a crystal.[1] But in a solution crystallization may involve not only change in orientation, as when opal is converted into chalcedony, but also change of place, an aggregation of certain molecules which previously were mixed up with others. This is illustrated by the 'clarification' of a tachylyte when the ultra-microscopic particles of iron-oxide in the brown glass begin to collect together in visible granules, by the formation of feathery groups of crystallites (hornblende) from the surrounding dusty glass in some of the Arran pitchstones, and in all holocrystalline rocks consisting of two or more minerals. This grouping of like with like is due to an attractive force which, under certain circumstances, though to a more limited extent, can also act in a body while it remains solid ; as when, in some stalactites, minutely-crystalline calcite becomes coarsely crystalline, or steel and other metals become crystalline under pressures and vibrations,[2] and glass softened by heat is devitrified. Any local discontinuity, such as the existence of an outer surface or of an included solid, is favourable to crystallization, because that is a process like building, and thus is facilitated by a ready-made foundation. Moreover, as heat is generally lost by radiation from the outer part of a mass, crystallization naturally begins here, at the coolest part. When the conditions in the neighbourhood are uniform, then, if crystallization starts from a (non-mathematical) point within the mass, it will proceed uniformly in all directions and produce a spherulite ; if from a line, an axiolite; if from a surface, some dependent form. In the case of a plane (such as the outside of a piece of glass) the crystallites might be arranged like a mass of parallel rods, but more usually, since certain spots in it afford slight advantages, they form tufts diverging from centres, which are occasionally so far separated as to produce 'hemispherical spherulites.'

As crystallization usually requires time,[3] a slow fall of temperature is favourable to it, and indirectly to the reduction of a solution supersaturated with one or more minerals to an eutectic, because thus the constituents in excess are separated out. Here we often meet with apparent anomalies, such as the separation of both quartz and felspar from an acid magma, or that of both felspar and augite from a basic one. These may be explained, either by slight

[1] The optical effects of strain in a colloid indicate a temporary orientation of its molecules.

[2] Journ. Iron & Steel Inst. vol. liv (1898) p. 185 & vol. lviii (1900) p. 60.

[3] Mr. J. E. Stead remarks, Journ. Iron & Steel Inst. vol. liii (1898) pp. 151–52, that 'the crystallization of steel requires a certain amount of time as well as a certain degree of heat.'

differences in the composition of the minerals present as conspicuous crystals and in the groundmass, or by variations in the amount of water in the mixture, for that also must produce some effect on the conditions of consolidation.

Before proceeding farther we shall find it convenient to give a brief summary of the different types of structure. These may be classified (more for convenience than as implying hard-and-fast divisions) as the linear and the granular. The linear may be subdivided into (*a*) the rectilinear, (*b*) the curvilinear.

Linear Structure.

(*a*) The rectilinear.—For this a mere mention will suffice: its earliest stage is the formation of microliths like the felspars in an andesitic glass, its latest that of the porphyritic crystals often found in holocrystalline rocks. The augites from near Predazzo, the leucites of Somma, the felspars of the Mairus porphyroid and the Lamorna granite (to quote a few conspicuous instances) probably imply that the magma in which they formed was at one time supersaturated with the constituents of a particular mineral, which were not indeed wholly removed by crystallization, but were, so to say, reduced by it, so that they could be kept in check by the representatives of other minerals—for I apprehend that the formation of an eutectic is equivalent to a temporary deadlock in a struggle for priority.

(*b*) The curvilinear, into which we have virtually been led in the last few words. It is represented in its first stage by trichites, but is usually found in groups, as in some spherulites and in the micrographic, or micropegmatitic structure,[1] of which that long known as graphic is only a variety. We shall find, I think, that so far as there is any difference between these two structures, it depends very largely on the nature of the obstruction offered.

Spherulitic structure in its simplest stage is apparently no more than a radial grouping of molecules,[2] as perhaps in some of the clear, almost structureless spherulites which on crossing the nicols give rather distinct black crosses; but it is generally associated (as taking place in a 'mineral mixture') with some amount of separation. Occasionally this is extrusive, as (to a slight extent) in ordinary banded spherulites, and more conspicuously in the holocrystalline spherulites of orbicular granite or corsite—but commonly the magma separates into two minerals (exclusive of minute iron-

[1] Now commonly designated the 'granophyric.' Apart from the fact that the word itself, like all but one ending in 'phyre' or 'phyric,' is nonsense, Vogelsang, its author (as I believe), used it in another and partly-appropriate sense.

[2] This must be the case in the spherulitic structure occasionally found in chalcedony.

oxide) of which one acts as a kind of matrix to the other.[1] At first, the crystal-growth in a spherulite is simply radial; but, after a time, the interstices between the growing 'stems' become sufficiently wide to allow them to throw off side-branches. These in some cases contrive to interlock and form a kind of mat of rectilinear branches,[2] but more commonly they interfere, with a result somewhat resembling that observed when trees in a wood are 'drawn' by being planted too closely.

But, as the history of the ordinary spherulite has been traced by Mr. Parkinson, I need say no more than that my conclusions accord with his, and that I regard the ordinary 'graphic' or 'pegmatitic' structure, whether on a minute or a large scale, as the result of a struggle for independent crystallization between two minerals (commonly felspar and quartz), one of which has gained a very slight advantage over the other in freezing. The crystals thus formed are skeleton-crystals, the intervening parts being occupied by a more or less continuous definite mineral, instead of by magma or aggregates such as iron-oxides; but we sometimes find that the one mineral, either in the outer part of a spherulite or a pegmatite, assumes (*b*) the curvilinear or a root-like growth. This is also a result of obstruction, but of a slightly-different kind; and its history I think can be inferred from a remarkable and suggestive experiment in the formation of colloid silica, described several years ago by Messrs. J. I'Anson & E. A. Pankhurst.[3] A certain amount of an alkaline carbonate was mixed with a strong solution of an alkaline silicate, and then some strong sulphuric acid was slowly discharged from a pipette at the bottom of the vessel containing the liquid. Bubbles of carbonic-acid gas formed immediately and rose upward, carrying with them some of the other acid. This on its part decomposed the alkaline silicate, causing precipitation of the silica, so that in a few minutes a tube of it was formed, reaching from the bottom to the surface of the solution. Its walls at first were very thin, but as the acid percolated through them the process of decomposition and deposition was maintained, and it continued so long as the agent was supplied, thus forming a hollow 'stalactite.' These stalactites, to quote the authors' words,

> 'do not grow up by any means in constantly straight regular forms, but assume irregular and branched ones, more like those of coral than anything else, according to the direction in which the bubbles of gas or the acid escape from the end, or from points of least resistance in the sides, of the tube.'[4]

I can see no other explanation of this wavy structure than a slightly-variable opposition to the passage of the disturbing agent; and thus regard the coralloid or root-like structure of a mineral in a rock as

[1] Though the two minerals are often hardly to be distinguished under the microscope, the published analyses of spherulites show that free quartz must be present as well as felspar.

[2] So far as my observations go, this is more usual in artificial glasses.

[3] Min. Mag. vol. v (1884) p. 34.

[4] *Op. cit.* p. 36.

indicating that the material of the one which it appears to penetrate, was in a rather more gelatinous condition than when the ordinary 'hebraic' type is produced. Mechanical resistance, as I have already pointed out,[1] facilitates an actinolitic growth in the direction of the strongest force of crystallization. If a crystal in development encounters an insurmountable obstacle, it is either diverted or compelled to fork; and, if the obstacles be both small and numerous, the process is repeated again and again. This, as has already been pointed out, is the explanation of frost-fronds, dendritic markings, and the like; and the more minute and numerous the obstacles (as on a roughened surface) the more the branches appear to curve (for a curve, to use mathematical language, is the limit of a polygon). Thus, the fact that spherulites often assume a lobed or root-like growth in their outermost parts, may be explained by the increasing viscosity of the glass from which they are being formed.

When crystals (for example, microliths) are forming in a magma, these will continue to be enlarged, provided the temperature remains high enough, until the necessary constituents are exhausted. The residual magma is then either a single mineral, such as augite in one case or quartz in another, or more often a mixture which, by the process of crystallization, has gradually become richer in water, and the presence of this last may itself determine whether a compound[2] is eutectic. When such an one has been formed, the temperature will fall for awhile without producing further crystallization; and this, when it occurs, will not come about by the gradual separation of a single mineral, but by simultaneous formation of all the components.

A mineral cannot be idiomorphic without having 'had its own way' during crystallization, so that a rectilinear and a curvilinear (or irregular) outline to the mineral constituents of a cooled rock mean differences in the history of solidification. Divergent groups of crystals, as we have seen, are indicative of opposition, the nature of which is implied by the character of the branching. Whether the latter be microscopic or megascopic probably depends on whether crystallization commences independently from many centres (that is, whether the conditions throughout the mass are very uniform), or whether growth begins around certain nuclei—such as previously-formed crystals of felspar, quartz, etc., and the fact that a pegmatitic or graphic structure is so often a 'groundmass characteristic' must not be overlooked.

Granular Structure.

We come next to the different forms of granular structure. In this also, so far as the boundaries are concerned, there is a rectilinear and a curvilinear type. When the former occurs, the

[1] See my remarks in Quart. Journ. Geol. Soc. vol. xlvii (1891) pp. 103–105.

[2] Thus a subsequent loss of water would mean supersaturation by the other minerals, and might account for their separation.

conditions of solidification must have given one of the constituent minerals, commonly the felspar, a very slight advantage over the other, and this structure generally belongs to both microgranites and ordinary granites. The curvilinear type, however, is seen in many compact felstones and in a large number of granitoid rocks, especially in that group (generally of pre-Cambrian age[1]) which were formerly supposed to have undergone metamorphism. I regard these curvilinear boundaries as signifying that the temperature remained steady at a height which, in a normal granite of corresponding coarseness, would have allowed felspar to separate from the residual quartz in the usual way, but that owing to some disturbing factor (probably an increased viscosity) the latter mineral had a greater power of resistance; so that a rectilinear boundary was impossible, because neither could definitely overcome the other. Thus, as we shall presently see, the significance of curvilinear boundaries to grains in a granular rock is very similar to that of root-like or wavy structure as opposed to rectilinear in a 'graphic' rock.

I do not forget that in holocrystalline igneous rocks a granular structure has been attributed to movement in the act of cooling, which has rubbed off the angles of crystals already formed by the resistance of the viscous residue. This is obviously a possibility, and I believe that conspicuous crystals are sometimes thus treated,[2] but we must remember that the residual magma which this explanation requires to be present would either crystallize independently as a groundmass (as in the cases just mentioned), or would be used up in augmenting, and thus repairing, the damaged crystals.

In the more compact felsitic rocks we not unfrequently find a slightly-variable structure, some patches being a little coarser than others—spherulites being restricted to particular bands, etc.: see Pl. XXVI, fig. 3. These may be attributed to slight local variations in chemical composition, with which we are familiar in ordinary fluxion-structure.[3]

Some compact felstones, when examined under the microscope, exhibit a close association of spherulitic, micrographic, and granular structures (the second being often root-like, and the third curvilinear in outline), the one apparently passing almost insensibly into the other: see Pl. XXVI, figs. 4, 5, & 6. The relation of the first to the second has already been noticed, and that which it bears to the third is shown by studying sections. As these become more nearly tangential, the radial is replaced by the granular structure, and the more crowded

[1] In these, as I have more than once pointed out, the structure often closely resembles that of a quartzite.

[2] This, as I have explained in Quart. Journ. Geol. Soc. vol. xlvii (1891) pp. 483–90, accounts for an occasional 'augen-structure' in rocks wherein there is evidence of tension but none of pressure.

[3] Something of the kind also occurs, as has been frequently noticed, in holocrystalline rocks. Often it is indicative of a partial melting-down of one rock by another, but sometimes is more suggestive of differentiation (prior to the movement) in a magma.

the crystallites in the former, the more irregular are the outlines in the latter. The three structures have much the same origin, but in two of them crystal-building, owing to local circumstances, has proceeded on a rather more definite plan than in the third; and we observe that the more root-like the micrographic structure the more irregular are the granular outlines. Thus the departure from a rectilinear habit in the components of a devitrified rock is a measure, figuratively speaking, of the severity of the struggle between them.

Secondary Devitrification.

We pass now to secondary devitrification. Here also the principles which we have endeavoured to establish may be applied. Although it would perhaps be rash to assert that the occurrence of spherulites invariably signifies an elevation of temperature almost enough to melt the glass, this is certainly most effective in producing them. We may even say that, in secondary devitrification (at ordinary temperatures, so far as we are aware), not only is the 'trachytoidal' (microlithic) structure unknown, but also, apart from spherulites, any form of rectilinear structure is rather rare; indeed, the circumstances under which we most commonly find the latter are themselves suggestive. It is associated with a perlitic structure (itself a very strong presumption in favour of the rock having once been a glass), and in close relation, as Mr. Parkinson and I have independently observed, with the perlitic cracks. To these the lines separating the quartz and felspar are often rudely perpendicular, so that the interval between two concentric cracks may be occupied by an alternation of these two minerals, while in uncracked portions of the slice they may appear as ordinary curvilinear grains. Naturally-devitrified rocks, without any perlitic cracks, commonly exhibit a speckly, rather minute, and irregularly-outlined structure, resembling that frequent in cherts. This might be expected, because the material of the latter probably crystallizes under constraint; for, in some cases, it was originally a colloid and subsequently became microcrystalline, in others the crystals in forming had to deal with mechanical obstacles (particles of clay, etc.). We sometimes find this speckly structure restricted to parts of a slice which are rendered less translucent by the presence of minute dust (probably ferruginous), while the clearer are more coarsely granular; or to parts which are free from perlitic cracks, the 'grain' becoming coarser when these appear.

The fact that curvilinear, more or less ragged-edged, granulation is the normal type in the secondary devitrification of a glassy rock points in the same direction, and is confirmed by the fact that annealed steel often shows the same structure.[1]

[1] See figures in Mr. Stead's paper on the 'Crystalline Structure of Iron & Steel' Journ. Iron & Steel Inst. vol. liii (1898), one or two of which might serve for outline-drawings of some felstones. Here the steel had been heated to a temperature rather above 750° C., and the coarseness of the granulation mainly depended on the time for which this had been maintained.

The devitrification of a volcanic glass implies, however, a stage beyond that of the formation of a chert. In the latter certain groups of adjacent silica-molecules have only to arrange themselves in a definite order [1]; but in the former a kind of sifting process is necessary—a change of place as well as of position—the silica-molecules gathering around one centre and those of an alumina-alkali-silicate around another, although the mass itself remains practically solid.[2]

A special type of this latter devitrification might be termed 'patchy or 'splotchy' (though perhaps poikilitic, as being less English, will be more generally acceptable). In it a number of molecules, perhaps already separated as in a spherulite, are locally re-arranged, so that a granular is superposed on a radial structure. In the absence of a spherulite we may regard this as merely a variety of the granular structure; although I suspect it to be even then secondary, the rock having already been very minutely devitrified. But when it occurs in a spherulite (sometimes making this far less distinct under crossed nicols than with ordinary transmitted light) we cannot doubt that it is not a primary structure. Here the formation has probably been facilitated by the fact that the component crystallites in small portions of the spherulites (as in a cone with a narrow angle) are already lying nearly parallel, so that only a small change in position is needed to bring them into line as parts of a crystalline grain. But if so, we may be asked why a spherulite is not converted into a series of radiating crystals showing in sections as isosceles triangles. The most probable answer is, that even in these spherulites the structure is not perfectly symmetrical; the radii may throw off side-branches (this is often very strongly marked in artificial glasses and slags) which cause confusion, or they may be modified in direction by the shape of the nucleus from which they have started whether that be a crystal previously formed or a cavity. Absolute symmetry is likely to exist but rarely, and this crystallizing force (if I may so call it) may be restricted in its effects within comparatively small limits, so that even if the apical part of a triangle (in sections) form one crystal, the basal may have to break up into two or three. Moreover, we have no reason for supposing this re-arrangement to begin at the centre of a spherulite and proceed outward. It is more likely to be set up at a series of independent points, where the slightest difference in conditions may suffice to initiate it.

One point in secondary (and in some cases also of primary) devitrification has often struck me as remarkable. When a granular structure is moderately coarse, the quartz is easily distinguished from the felspar; but often in spherulites, and almost invariably in the 'patchy' devitrification, the former mineral is hardly visible,

[1] As we might imagine eggs in a basket arranging themselves with all their longer axes parallel.

[2] The possibility of such a movement was demonstrated by the late Sir William Roberts-Austen in his experiments on the migration of gold into lead, Phil. Trans. Roy. Soc. A, vol. clxxxvii (1896) p. 383.

though a chemical analysis proves that there must be a considerable amount of free silica present. For instance, in a spherulite from the Yellowstone Park, the felspar is in it roughly as 169 to 100; in one from Corriegills shore (Arran), as 194 to 100; and in one from Boulay Bay, as 182 to 100.[1] In the first case Mr. Parkinson suggests a very probable explanation of the invisibility of the silica; but in the second, third, and other cases of secondary devitrification that I have examined, I have observed that under a high power one of the apparently-felspathic grains or patches, instead of appearing homogeneous, as in ordinary primary devitrification, either seems to be speckled with a material which acts but feebly on polarized light, or sometimes even suggests the presence of an almost ultramicroscopic graphic structure, so that I suspect the apparent felspar to be really a compound of that mineral and quartz.

Eutectic Structures.

Mr. Teall pointed out, in his most suggestive Presidential Address,[2] that, in accordance with Mr. J. E. Stead's experiments on alloys, eutectic compounds are especially favourable to the formation of spherulitic and graphic structures; and I have spent some time in calculating from rock-analyses the proportion of felspar to quartz, in order to see whether the ratio which obtained in one case (163 : 100) generally held good. The results, however, as might be inferred from the figures quoted above, are not very satisfactory, and I am not sanguine of success, with our present data. In a rock the problem usually is much less simple than in an alloy, for it consists in finding the eutectic mixture, not of two minerals, but of three or four; since at least two species of felspar must often be present, besides quartz and water, while in regard to the last the amount now present affords no indication of what was originally dissolved in the magma. We might obtain trustworthy results from analyses containing only potash or soda, but these are extremely rare, and even though the substitution of a small quantity of the one alkali for the other may not alter the species of the felspar, yet it may produce some effect on the crystallizing temperature of the mineral, and must, I think, modify that of the eutectic. But that any eutectic is particularly favourable to the formation of spherulitic and pegmatitic structures, may now, I think, be taken for granted; also that the coarseness or fineness of this structure is a question of temperature and time[3] (which is to some extent applicable even to secondary devitrification). Moreover, as I hope that I have made clear, a rectilinear or a curvilinear type of growth is probably dependent on

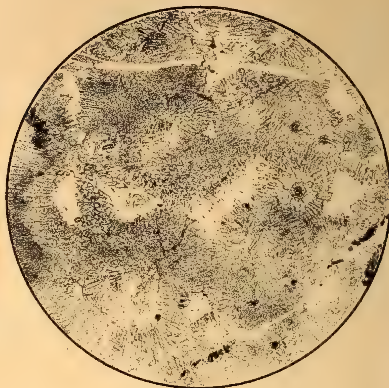
[1] That is to say, the free silica is always more than one third of the mass. In each case the felspar is of two species, orthoclase and albite—the latter predominating in the second case.

[2] Quart. Journ. Geol. Soc. vol. lvii (1901) p. lxxv.

[3] As this makes it a function of two variables we must remember that (within limits) an increase in the one may compensate for a decrease in the other.

1. ×20.

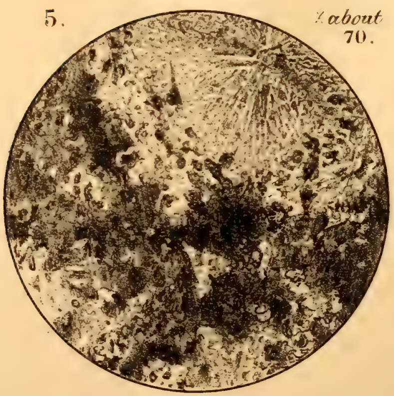
2. ×20.



3. ×20.

4. ×20.

5. × about 70.



6. × about 100.

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DEVITRIFICATION IN GLASSY IGNEOUS ROCKS.

the amount of resistance offered to the mineral which takes the lead in crystallizing.

EXPLANATION OF PLATE XXVI.

Fig. 1. Obsidian Cliff. The feather-like crystals characteristic of the porous patches or spherulites. Crossed nicols. × 20.

2. Vicart Cliffs (Jersey). Example of primary devitrification, in which the early crystallization of superfluous silica has apparently been followed by an eutectic. Ordinary light. × 20.

3. From Cadhat Plain (Sokotra). Shows slight fluxional, with consequent modification of spherulitic, structure: the latter in parts of the slice passing into a more or less root-like or speckled structure (small scattered grains of quartz and felspar). A compact quartz-felsite, which probably was so from the first. Crossed nicols. × 20.

4. From Tan-y-maes (Caernarvonshire). Spherulitic structure, often rather tufted and growing round felspar-crystals (less definitely connected with the quartz). Small spherulites occur in the matrix of the rock, which sometimes exhibits a more or less root-like structure, apparently connected with the other, and sometimes seems to be simply speckled, but occasionally approaches micrographic. A spherulitic quartz-felsite. Crossed nicols. × 20.

5. North-western end of Girgha range, near Hadibu Plain (Sokotra). The matrix exhibits a sort of 'vermicular' structure, which here and there (as in the north-eastern corner of the drawing) is grouped into a rather irregular spherulite with root-like branches. A compact quartz-felsite. Crossed nicols. × about 70.

6. Base of the cliff, Corriegills shore (Isle of Arran). This rock (see Geol. Mag. 1877, pp. 506–509) is here and there slightly spherulitic, and one some distance away, probably corresponding with it, is markedly so. It is also slightly fluxional, and exhibits conspicuously the root-like structure shown in the figure. The rock is from the base of a rather compact felsite, softened or locally melted by an intrusive pitchstone. Crossed nicols. × about 100.

Discussion.

The Chairman (Mr. Teall) said that he was extremely glad to see attention directed to the work of those specialists who were engaged in the study of alloys. Many of their results would probably be found applicable to rocks. At the same time, caution was needful in drawing conclusions from one set of phenomena to another. Messrs. Haycock & Nevill, whose results were not yet fully published, had shown that, after complete solidification, very important changes took place in copper-and-tin alloys, so that the structures and the compounds produced at earlier stages of consolidation disappeared, to be replaced by later products. It was not improbable that similar changes would be found to have taken place in many rocks, even in such as differed totally in composition from felsites or pitchstones.

Prof. G. A. J. Cole congratulated the Authors on continuing to add new observations to those brought forward on devitrification during the last thirty years. The question of eutectic association of various minerals might possibly be pushed too far, since the conditions prevalent in the earth's crust might allow one pair of minerals

to form such an association, and yet exclude other associations. Quartz and an alkali-felspar very commonly occurred in suitable proportions, as the Chairman had pointed out; but conditions might never arise such as would permit the entry of molecules of a third or fourth mineral into the quartz-felspar associations, as the Authors appeared to have suggested.

Prof. Judd expressed his agreement with the many points which had been brought out so clearly by the Authors, and concurred with the Chairman in valuing the high importance of Messrs. Haycock & Nevill's researches. Experimenters with alloys were able to regulate at their pleasure temperatures and proportions; on the other hand, petrographers had the advantage of being able to use polarized light.

Prof. Sollas congratulated the Authors on their accurate and logically-consecutive description of the phenomena. He thought that the investigation of mixtures of transparent salts would afford more valuable information than that obtained from the study of alloys. With regard to the use of the term 'devitrification,' that appeared to postulate the previous existence of glass, yet many of the phenomena described might be due to direct crystallization from a molten magma.

Mr. Parkinson thanked the Fellows for the way in which his remarks had been received.

Prof. Bonney expressed his thanks to the Fellows of the Society for their kindly reception of his paper. He was glad to use the opportunity of acknowledging the help which he had received from the Chairman's Presidential Address, and from the work on alloys of Messrs. Stead, Haycock, Nevill, and others. He explained, in reply to Prof. Cole, that he laid no stress on the possible presence of a ferromagnesian mineral in an eutectic of a granitoid character. Even without it we had an indeterminate equation of four variables. In reply to Prof. Sollas, he said that Miss Raisin had formerly made some experiments of crystallization in a colloid, but had not been able to carry them far. He admitted that the term 'devitrification' had to be used rather vaguely, but thought that the inclusive sense was defensible.

36. *The* TOARCIAN *of* BREDON HILL,[1] *and a* COMPARISON *with* DEPOSITS ELSEWHERE. BY S. S. BUCKMAN, Esq., F.G.S. (Read May 27th, 1903.)

CONTENTS.

I. GEOLOGY.

THE Upper Lias (G 3) of Bredon Hill is shown on the Geological-Survey map as more than 300 feet in thickness. It is said to be as much as 380 feet thick, whereas at Wotton-under-Edge, some 36 miles to the south, it is said to be only 10 feet.[2] But at the former locality the Inferior Oolite (G 5) is represented as resting directly on the Upper Lias (G 3); at the latter locality there is shown, between Inferior Oolite and Upper Lias, a development of some 150 feet of strata called 'Midford Sand' (G 4)—the Cotteswold Sands overlain by the Cephalopod-Bed. The question often presented itself to my mind—Were the two so-called 'series' of Upper Lias the same, or was not the Upper Lias of Bredon Hill really much more than the Upper Lias of Wotton, so that there was not a true comparison? Was it not an argillaceous condition of the sands and the overlying Cephalopod-Bed?

Some few years ago I was able to answer this question partly in the affirmative. On the north slope of Bredon Hill, I found in some argillaceous stones in a gateway, many feet below the yellow limestone of the Inferior Oolite, portions of ammonites indicative of beds contemporaneous with the Cephalopod-Bed of the Cotteswolds: they indicated strata of the hemeræ *Moorei*, *dispansi*, and *Struckmanni*.

When the Cotteswold Naturalists' Field-Club visited Overbury on the south side of Bredon Hill, in 1902, the members found in the gravel-pit many ammonites confirming my discovery. At a subsequent visit, which I paid with Mr. L. Richardson, F.G.S., other confirmative fossils were found. From them there was evidence not only for strata contemporaneous with the Cephalopod-Bed, but also with the Cotteswold Sands; these evidently formed part of the so-called 'Upper Lias' at Bredon Hill. But as the specimens were only obtained from the fallen blocks in a gravel-pit, the actual thickness of the deposits could not be ascertained.

[1] Bredon Hill is partly in Worcestershire, and partly in Gloucestershire. For an account of the Aalenian deposits of the hill, see L. Richardson, 'Inf. Oolite at Bredon Hill' Geol. Mag. 1902, p. 513.

[2] See, for instance, H. B. Woodward's 'Geology of England & Wales' 2nd ed. (1887) p. 276.

It seems desirable to state exactly the nature of the evidence obtained. The stones in the gateway were typical 'Upper Lias' nodules; the gateway itself was on 'Upper Lias' Clay. Anyone who knows how a farmer will take the least possible trouble to obtain materials to harden a field-gateway, especially one where there is no cart-traffic of importance, can judge that these nodules were picked up close to the gate, and that they are, in every probability, within a few feet of their vertical position. Then the hill is completely isolated: the stones were about on the 800-foot contour-line, which is a steep climb of some 650 feet up from the vale.

As regards the finds in the gravel-pit, the material of this pit is the scree or talus of the hillside. It is angular gravel, not worn, and it has not been, in a strict sense, transported. It is material that has slid down from the hill, and is comparable to the talus so often seen at the foot of a quarry or escarpment, or of a railway-cutting. Its value as evidence for what is in the hill above is the same as that of tumbled blocks found in such places as quarries, or cuttings; but it does not indicate the exact position, nor does it give the actual thickness. But the relative sequence of fossiliferous blocks may be known by the sequence which has been ascertained elsewhere.

To show what the finds at Bredon Hill indicate, the following Table is given, stating the sequence of hemeræ, and indicating the various deposits made, in the Cotteswolds, during those times.

TABLE I.—HEMERAL AND STRATAL SEQUENCE.

Hemeræ.	*Deposits in the Cotteswolds.*	*Stages.*
Scissi	Sandy Ferruginous Beds.	Aalenian.[1]
Opaliniformis	Hard capping to the Cephalopod-Bed.	
Aalensis	Cephalopod-Bed.	
Moorei		Toarcian.[1]
Dumortieriæ		
Dispansi		
Struckmanni		
Striatuli		
Variabilis	Cotteswold Sands.	
Lilli		
Bifrontis	Upper Lias Clay.	
Falciferi		

[1] The term 'Aalenian,' as now used, replaces in part the term 'Upper Toarcian' employed in my paper on 'The Cotteswold, &c. Sands' Quart. Journ. Geol. Soc. vol. xlv (1889) pp. 473, etc.; and the term 'Toarcian' is almost equal to the term 'Lower Toarcian' in that paper (see below, p. 457).

At Wotton the strata of the hemeræ *bifrontis–falciferi* are called Upper Lias (G 3), and the other Toarcian strata, Midford Sand (G 4). At Bredon, strata of the hemeræ *Moorei* to *falciferi* are all termed Upper Lias (G 3).

To take the evidence:—To indicate strata of the hemera *Lilli*, there is a specimen of *Hildoceras semipolitum*, S. Buckm.[1] (B); for hemera *variabilis* the specimen named *Denckmannia bredonensis* (B), and a species of *Brodiceras* (B); for hemera *Struckmanni*, species of *Pseudogrammoceras* (A & B)[2]; for hemera *dispansi*, several specimens of *Phlyseogrammoceras dispansum*, Lycett (A & B); for hemera *Dumortieriæ* a specimen of *Catulloceras Dumortieri* (Thioll.), found by me some years ago in a gravel-pit at Beckford, near the south flank of the hill[3]; for hemera *Moorei*, two specimens of *Rhynchonella cynica*, S. Buckm. (B), and specimens of a fine-ribbed *Dumortieria* (A).

The matrix in which these species are found is of somewhat the same general facies—a greyish, or bluish-grey argillaceous stone; but there are certain characters which are easily recognizable as distinctive of particular layers. So, although the thickness of the deposits be not known, the following may be given as the stratigraphical sequence:—

Table II.—Toarcian of Bredon Hill.

Hemeræ.	*Character of Deposit.*
Moorei	Grey, somewhat sandy stone.
Dumortieriæ	Light yellow, argillaceous.
Dispansi	Greyish-yellow argillaceous stone, with many comminuted shell-fragments.
Struckmanni	Grey argillaceous stone, with some shell-fragments and many small shells.
Variabilis	Greenish-grey stone, almost made up of comminuted fragments which have a greenish tinge.
Lilli	Darkish-grey argillaceous stone.

In breaking the stones of the gravel-pit, many specimens of *Orbiculoidea* were found. There are apparently three or four species. From the lithic characters of the matrices tabulated above they can be dated, with some certainty, as follows:—

Moorei (?). Small species (perhaps two?). Numerous; a score of specimens on a surface of 4 square inches.
Dispansi. A small species, rather conical.
Struckmanni. A flattish species, much larger, about 10 mm. in length.
Lilli. A small species.

These species are new to this country. There is only one species of *Orbiculoidea* (olim *Discina*), recorded by Davidson[4] from a similar horizon: that is certainly distinct.

[1] See 'Emendations of Ammonite-Nomenclature' p. 4, Cheltenham, 1902.
[2] (A) indicates the stones on the gateway; (B) those from the gravel-pit at Overbury.
[3] The gravel in this case is stream-transported, and is in the vale, about a mile from the hill.
[4] 'Monogr. Brit. Foss. Brach.' vol. iv, pt. ii (1878) Suppl. p. 233. (Pal. Soc. vol. xxxii.)

The Upper Lias at Bredon Hill, then, may be said to be, on the fossil evidence obtained, equal not only to the Upper Lias of the Cotteswolds—Wotton-under-Edge, for example—but also to the overlying Cotteswold Sands and Cephalopod-Bed. If the thickness of these strata in the Cotteswolds be compared with that of the Upper Lias at Bredon, it will be found that they are not so dissimilar, That is the comparison which should be made; but as the statement stands in the maps and text-books, it seems as if only the strata of the hemeræ *bifrontis–falciferi*, which are 10 feet thick at Wotton, had increased to become 380 feet at Bredon. The evidence obtained at Bredon makes against that—it indicates that there are strata of more than the two hemeræ.

II. Comparison with the Cotteswolds.

Opportunity may now be taken to compare the Toarcian deposits of Bredon Hill with those of certain Cotteswold localities, places famous for the Cephalopod-Bed and Cotteswold Sands; the more so as certain supplementary measurements of the latter deposit can now be given. These measurements are the result of work with the level, taken, in two cases (Frocester Hill and Coaley Wood), with the help of Mr. Charles Upton. They supplement, and to a certain extent correct, the data given by me in 'Monogr. Inf. Ool. Ammon.' pt. ii, Pal. Soc. vol. xli (1888) pp. 43–47, and in Quart. Journ. Geol. Soc. vol. xlv (1889) pp. 440–474.

The following table embodies the information concerning four Cotteswold localities.

Table III.—The Cotteswolds.—Thicknesses of certain Deposits in passing from North to South.

Toarcian deposits.	*Standish Beacon.*[1] ('Haresfield').	*Frocester Hill.*	*Coaley Wood.*	*Stinchcombe Hill.*[5]	*Remarks.*
	Feet.	*Feet.*	*Feet.*	*Feet.*	[1] Alternative reading: Cotteswold Sands 210 feet; Clay 110.
Cephalopod-Bed	2	8	$3\frac{1}{2}$	[8][4]	[2] Cotteswold Sands = *variabilis* 106 ft.; *Lilli* 138 ft.
Cotteswold Sands ...	190	244[2]	186[3]	195	[3] *variabilis* 72 ft.; *Lilli* 114 feet.
Upper Lias Clay	130	64	[40][4]	18	[4] Estimates. [5] Stinchcombe Hill is 3 miles from Wotton-under-Edge.
Total ...	322	316	$229\frac{1}{2}$	221	

Coaley Wood:—Amend section given in Quart. Journ. Geol. Soc. vol. xlv (1889) p. 444, thus: Beds 9 to 13, 61 feet. Beds 16 *a* & 17, 39 feet. Bed 18, 75 feet.

The division between sand and clay must not be regarded as a definite horizon. The passage is to a certain extent gradual, and in most cases is only shown by the spring-level, which again is variable according to locality and to season.

Nor must it be supposed that at the base of the Sands commence the strata of the *Lilli* hemera. If this happen at one place, it may not at another. The clay-level is known to rise higher northwards: near Cheltenham Mr. L. Richardson found evidence of the strata of *Lilli* hemera in so-called 'Upper Lias' clay[1]; and eastwards, at Chalford, clayey conditions and the water-level rise to the top of the *variabilis*-beds.

In the foregoing measurements one noticeable point is that the Cotteswold Sands work out to a much greater thickness than had been supposed, especially at Frocester Hill.

To make just comparison between these localities and Bredon Hill, not merely the Upper Lias Clay is to be taken, but the total Toarcian deposits. Thus we get at Bredon (Toarcian) a thickness said to be 380 feet, and these Cotteswold localities working out from 221 to 322 feet. Stinchcombe Hill may stand well enough for Wotton. Instead of the Upper Lias at Wotton being 10 feet, it should read as 220 feet to compare with Bredon's 380 feet.

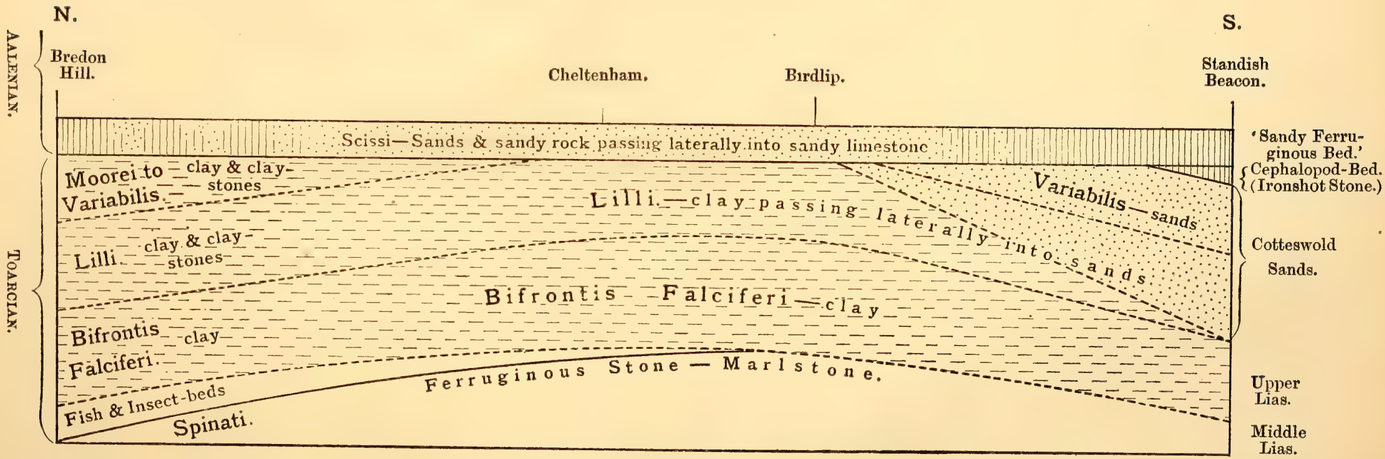
The Toarcian deposits do not maintain their full sequence from Bredon Hill to the Frocester district of the Cotteswolds; like other Jurassic beds, they show evidence of anticlines and penecontemporaneous erosion. At Standish Beacon there is non-sequence, by erosion pre-*Dumortieriæ*, post-*variabilis*—the effect perhaps of the Birdlip anticline, noticeable in the Bajocian Denudation.[2] Towards Birdlip the Cotteswold Sands thin considerably; at or before Birdlip they fail. What are mapped as Midford Sands (G 4) on the Geological-Survey map in the district north of Birdlip, are not the Toarcian or Cotteswold Sands, as to the south of that place, but Aalenian Sands, the equivalent of the Northampton Sands—the strata of the *scissi* hemera (G 5). And near Cheltenham these strata rest directly upon clays of the date of *Lilli* hemera—100 feet perhaps of deposit as compared with Standish are gone; but shales of *Lilli* hemera are replaced by sands at Standish.

At Bredon Hill the sequence is complete, or nearly so, again. But Bredon, it may be noted, lies exactly in the line of the Cleeve-Hill syncline, so conspicuous in connection with the Bajocian Denudation. The persistence of synclines is here illustrated. A small syncline formed in about Toarcian times saved the Toarcian strata of Bredon Hill: a more pronounced syncline in Tertiary times saved Bredon Hill itself.

[1] 'A fragment of a whorl of *Lillia*, most probably *Lilli*, was obtained from a hard nodule embedded in clay, in the ridge connecting the spur of Wistley Hill overlooking Vineyards Farm with the main hill-mass.'—L. Richardson, *in litt.*

[2] S. S. Buckman, 'Bajocian & Contiguous Deposits in the North Cotteswolds Quart. Journ. Geol. Soc. vol. lvii (1901) pl. vi.

TABLE IV.—DIAGRAM OF THE STRATA FROM BREDON HILL TO STANDISH.



Scales:- Horizontal, 1 inch = 4 miles.
Vertical, 1 mm. = 10 feet; 1 inch = 250 feet.

The appended diagram (Table IV) probably represents the relations of the Toarcian to the Aalenian strata, from Bredon Hill to Standish Beacon—interpreting the evidence of a non-sequence in the Cheltenham district as indicating an anticline in the neighbourhood, and suggesting that such anticline probably coincides with the Birdlip axis, noted in connection with similar anticlines in Bajocian and Aalenian strata.[1] The diagram also shows the varying lithic facies of the strata in question; and that the lithological planes run somewhat obliquely in regard to the palæontological horizons. Somewhere in the Birdlip neighbourhood the Aalenian Sands may be expected to rest directly upon the Toarcian or Cotteswold Sands—a curious result, which would give an apparently-lateral continuity of sandy deposits, when it is really superposition and a non-sequence.

III. Comparison of the Cotteswolds and Dorset.

While upon the subject of the development of sands, it may be useful to compare certain Toarcian (and some Aalenian) strata of the Dorset coast with those of the Cotteswolds. The Bridport Sands of the Dorset coast are much later in date than the Cotteswold Sands; they did not begin to be deposited until some time after the Cotteswold Sands had ceased—they are, in fact, four hemeræ later.

I took the opportunity, some years ago, of measuring them with the level, in the same way as I had done the Cotteswold Sands; and also, where possible, I measured them with the foot-rule up road-cuttings, examining the different layers of nodules. They yield sometimes a very fine series of ammonites, but a fauna quite distinct from that of the Cotteswold Sands. The sequence which they show is of particular interest: the manner in which the strata with the *aalensis*-type of ammonite follow those with fine-ribbed *Dumortieriæ* of the *Moorei*-type is especially noticeable. This can be appreciated in the thick deposits of the Dorset coast, whereas in the thin strata of the Cotteswold Cephalopod-Bed the sequence is difficult to recognize.

Table V (p. 452) embodies a comparison of the Cotteswold and Dorset strata, with some remarks.

It may be noticed that the periods of maximum and minimum deposits just interchange in the two areas. During the hemeræ *falciferi* to *variabilis*, thick deposits of clay and sands were being laid down on the Cotteswolds, but thin deposits of limestone in the Dorset coast-area. During and after the time of *Dumortieriæ*, however, the state of affairs is just the reverse, thin limestones prevailing in the Cotteswolds, thick sands and clays in Dorset.

This is a matter of some biological importance. Morris & Lycett, looking at the Cotteswold Cephalopod-Bed, considered that the

[1] 'Bajocian, &c. in the North Cotteswolds' Quart. Journ. Geol. Soc. vol. lvii (1901) pl. vi.

Table V.—The Cotteswolds and Dorset.—Comparative Thicknesses of Deposits laid down during similar Times in the two Areas.

Hemeræ.	*Cotteswolds:—approximate average.*	*Dorset Coast:—Chideock.*	*Remarks.*
	Feet.	*Feet.*	Yeovil Sands = strata of *Moorei* and *Dumortieriæ* hemeræ.
Opaliniformis and *Aalensis.*	2	37	Bridport Sands = strata of *opaliniformis-Moorei* hemeræ and part *Dumortieriæ*.
Moorei and *Dumortieriæ.*	6	199	Upper Lias Clay of Down Cliffs, Dorset Coast = strata of *Dumortieriæ* hemera (in part).
Dispansi to *Striatuli.*	2	a few inches.	Strata of *dispansi* hemera as sands in Somerset, attain the thickness of perhaps 50 feet.
Variabilis to *Falciferi.*	300	a few inches.	Strata of *Struckmanni* hemera as Midford Sands at Bath, attain a thickness of about 70 or more feet.
			Cotteswold Sands = strata of *variabilis* and *Lilli* hemeræ.
			Upper Lias of Bredon = strata of *Moorei* to *falciferi* hemeræ, and perhaps earlier.

ammonites were overwhelmed by inundations of mud, and that, therefore, the time taken to deposit the bed was small.[1] When, however, this Cephalopod-Bed is analysed into some six divisions, each with its particular fauna, and when the strata are found to increase perhaps a hundredfold in thickness in other localities, it is seen that the Cephalopod-Bed was a slow deposit, and that the number of specimens in a thin band of rock is not due to any swarming of individuals at the time, but to long-continued accumulations of shells where there was a great paucity of sediment.

IV. Comparison with Normandy.

While the subject of the Toarcian deposits is being considered, it may not be uninteresting to make a comparison with an exposure in Normandy. There is a section at Tilly-sur-Seulles (near Caen) which is very interesting, because it shows in a few feet a sequence

[1] 'Monograph of the Great Oolite Mollusca' p. 3. (Pal. Soc. vol. iv, 1850.) See also my 'Monogr. Inf. Ool. Ammon.' pt. ix, p. 446. (Pal. Soc. vol. xlviii, 1894.)

from Lower Lias to Inferior Oolite. It is a place where paucity of accumulation obtained for a long time.

Its Toarcian deposits show a thickness of only some 23 feet, and yet the faunal sequence is nearly complete. The lower 15 feet have great resemblance to the Toarcian deposits of North-West Gloucestershire, as, for instance, those at Dumbleton, even to showing the fine paper-shales; only the thickness at Dumbleton is much greater—it must be 100 to 150 feet. I append a description of the section.

SECTION NO. 1 AT TILLY-SUR-SEULLES (CALVADOS).

[From a diagram drawn for me on the spot by Dr. Louis Brasil. My own notes are in square brackets.]

Flint-nodules with *Murchisonæ*.	○ ○ ○ ○ ○ *Opalinus.* [Opalinoid.]
[About 18 feet.]	Nodules with *Moorei.*
	Dumortieria.
	Striatulum.
	Variabilis.
	Clay with *bifrons* and *communis.*
	Bifrons.
[About 15 feet.]	*Falciferum.* *Annulatus.* [Paper-shales like Dumbleton.]
	Rhynchonella pygmæa.
Spinatus. [*Rhynchonella tetrahedra.*]	[Rock-Bed.]
	[Rock-Bed.]
[About 20 feet.]	Middle Lias. *Æg. planicosta*=[*Liparoceras capricornu* and *Microceras gagateum.*] *Wald. numismalis.* *Spiriferina pinguis.*
	Upper part of Lower Lias. *Rhynch. Thalia.* *Gryphæa Maccullochi.*

I had time to investigate in some detail the strata in this section which are equivalent to the Cotteswold Sands and the Cephalopod-Bed. The following is the result:—

SECTION No. 2 AT TILLY-SUR-SEULLES (CALVADOS). July, 1895.

	Hemeræ.	TOARCIAN.	Thickness in Ft. ins.	Thickness in Ft. ins.
Aalenian.		1. Nodules.		
		2. Clay .... about		6 0
		3. Clay. *Terebratula* of the *punctata*-stock .... from base	3 6	
	Aalensis	*Ammonites* cf. *aalensis*-group ,,	2 0	
	Moorei	Numerous species of *Dumortieria* in the lower 2 feet. Compressed *Dumortieriæ* at a higher level than the		
	Dumortieriæ.	more inflated forms—confirmed by Dr. Brasil. *Dumortieria* cf. *prisca* in lower 6 inches		5 6
	Dispansi (?).	4. Fragment of *Hammatoceras (?)* on top of stone, with no other fossils found		0 4
	Struckmanni.	5. Stone with *Pseudogrammocerata* of the *fallaciosum* and *Bingmanni*-type, and cf. *dœrntense*		0 5
	Striatuli.	6. Stone with *Grammoceras striatulum* common, and *Haugia Eseri*	0 5	
		6 *a.* Clay and claystone, chiefly the latter; *Grammoceras striatulum* common.	1 0	
		6 *b.* As above, and with a doubtful fragment of the *Pseudogrammoceras fallaciosum*-group.....................	1 9	3 2
	Variabilis.	7. Clay with *Haugia* aff. *navis* at bottom		0 6
	Bifrontis.	8. Blue earthy stone, with *Hildoceras bifrons* and *Dactyliocerata*		1 0

Here I found just the same faunal sequence as I had noted for Gloucestershire, which in the main had been already observed by Dr. Louis Brasil, who took me to the section. But he had not separated the strata with the *fallaciosum*-type of ammonite *(Pseudogrammoceras)* from the beds with the *striatulum*-type *(Grammoceras)*. However, I found that here, as in Gloucestershire, there was the same sequence—*Pseudogrammoceras* certainly above the chief horizon of *striatulum*.

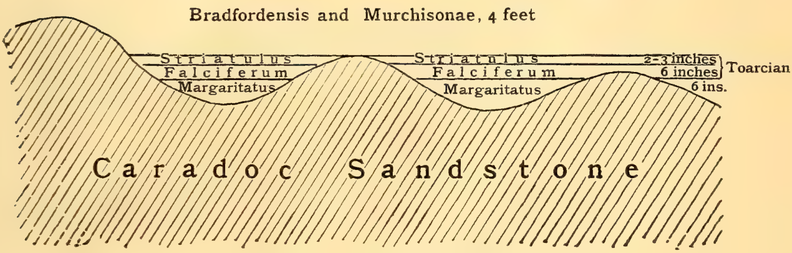
The persistence of clay in this section right up into what we are accustomed to speak of as 'Inferior Oolite' is interesting; it shows the little value of distinctions founded on lithic features. And the 'Midford Sands' one may look for in vain, though the fauna is well shown.[1]

[1] The ammonites of the genus *Dumortieria* are particularly noticeable. The bulk of them are of the type of *Dumortieria subundulata* (Branco), as delineated in my 'Monograph of the Inf. Ool. Ammon.' pt. vi, pl. xlv. (Pal. Soc. vol. xlv, 1892.)

The interesting stratal feature, however, in comparison with Dorset and the Cotteswolds, is that here the Toarcian is thin altogether; it is not thick at the beginning and thin at the end, as in the Cotteswolds, nor thin in the beginning and thick at the end, as in Dorset.

At another section near Caen, the Toarcian was much more reduced. There was only about 8 inches of it, and that in pockets in Caradoc Sandstone. It was limestone (and most of it crinoidal limestone), resting on conglomeratic sandstone with crinoids, belonging, on Dr. Brasil's authority, to the zone of *Ammonites margaritatus*. The following is the sketch that I made:—

Diagram of an exposure at May-sur-Orne (Calvados). July, 1895.



[The top of the *striatulum*-bed was eroded.]

V. Chronometry of the Toarcian.

In some districts—East Gloucestershire for instance—only a few feet of Toarcian are found separating the Inferior Oolite (Aalenian) from the Middle Lias (Pliensbachian). But what is the true time-interval in such a case? In West Gloucestershire—the western slope of the Cotteswolds—there were some 300 feet of strata laid down during this time-interval. This is not, however, the full measure of work accomplished: all but a few feet of these 300 belong to the early part of the Toarcian Stage. The thin deposits of the later part of the Toarcian Stage in the Cotteswolds give no true value for time-measurement; but a juster estimate can be obtained from the thick deposits of the Dorset coast, which belong to the later part of the Toarcian. So, in order to obtain a more correct estimate of the amount of work accomplished in the way of deposition, it is necessary to take the times during which the strata of the Toarcian Stage were laid down, and see how much work was accomplished during each one of them. The south-west counties of England yield the following results, so far as investigations have yet proceeded:—

TABLE VI.

Hemeræ.	Approximate maxima of deposits in feet.
Moorei / *Dumortieriæ*	199
Dispansi	50
Struckmanni	70
Striatuli	20
Variabilis	100
Lilli	130
Bifrontis / *Falciferi*	150
Total	719

Taking, therefore, the various maxima of deposits in the South-West of England, it is seen that the work accomplished during the time of the Toarcian Stage is represented by a deposition of some 700 feet of strata. The time during which this work was performed is divided into about nine hemeræ, so that the time-value of a hemera, on this evidence, is equal to the time taken to deposit about 80 feet of strata on an average.[1]

VI. RETROSPECT.

Now that the faunal contents of the various Sands are definitely known, the old, much-debated question, whether the Sands are Liassic or Oolitic, may be considered as settled.

In different localities the Sands are of different dates. Sometimes they are contemporaneous with what is called Inferior Oolite elsewhere, sometimes with what is called Upper Lias a few miles away.

Taking the Toarcian Stage to include strata up to the deposit dated hemera *Moorei*, and calling this 'Upper Lias' in a general sense, and taking the Aalenian Stage for deposits of later date = Lower Inferior Oolite, then it may be said that the Northampton Sands and the so-called 'Midford Sands' (G 4) of the North Cotteswolds are early Aalenian; the Bridport Sands are in part Aalenian, in part Toarcian; the Yeovil Sands are Toarcian; the Midford Sands of Midford (Bath) are Toarcian, but post-*striatuli*; the Cotteswold Sands, so-called 'Midford Sands (G 4)' of the Mid- and South Cotteswolds are Toarcian, but pre-*striatuli*. The Harford Sands of the eastern part of the Cotteswolds are late Aalenian.

It seems desirable to drop the term 'Midford Sands' in its wide sense. It suggests, as between strata of different localities, contemporaneity where there is sequence; in other cases, sequence where there is contemporaneity. The local names for the Sands may be retained as useful, colloquial, stratigraphical terms. Where

[1] Strata of hemera *acuti* have not been considered—they are not definitely developed in the districts investigated.

it is desirable to note a local sandy development of Upper Lias, as in the case of the Cotteswold Sands, which are of earlier date than the Upper Lias (G 3) of the Dorset coast, but are now called Midford Sands (G 4)—then they might be distinguished as G 3 with certain marks to denote the lithic change.

The following emendations in Prof. Renevier's 'Chronographe Géologique,' C.R. Congrès Géol. Int. (6me Session, Lausanne, 1894) 1897, p. 647, may be made with regard to these entries:—

'Micaceous Sands = Grès jaune des Cotteswold-Hills (Angleterre). BAJOCIEN inférieur.'

For this read:—

'Micaceous Sands = Grès jaune du côté oriental des Cotteswold Hills, Angleterre (Harford Sands). AALÉNIEN supérieur.

'Micaceous Sands = Grès jaune du côté occidental des Cotteswold Hills (Cotteswold Sands). TOARCIEN, pre-*striatuli*.'

'Midford Sands = Grès ferrugineux à *Rhynchonella cynocephala*[1] de N. Angleterre. AALÉNIEN inférieur.'

For this read:—

'Midford Sands = Grès jaune des environs de Midford (Bath) Somerset, S.O Angleterre. TOARCIEN, post-*striatuli*.

'Midford Sands, *sensu lato* = Grès jaune de S.O. Angleterre (G 4). AALÉNIEN et/ou TOARCIEN.'

VII. Comparison of Terms.

The following Table shows the correspondence between the terms used in a communication on the Cotteswold, etc. Sands published in vol. xlv of this Journal (1889) and those employed in the present paper. It will enable the remarks made in the present communication to be understood, with reference to the various sections there given. It will also be useful as showing the present interpretation of the stratigraphical names used in regard to sections in the early parts of my Monograph on the Inferior-Oolite Ammonites (Pal. Soc.).

TABLE VII.—COMPARISON OF TERMS.

	'Cotteswold, &c. Sands.' Quart. Journ. Geol. Soc. vol. xlv (1889) pp. 440–74.			Present paper.	
Lower Toarcian.	*Opalinum*-zone.	*Opalinum*-beds =[2]	=	*Scissi.* *Opaliniformis.*	Aalenian Stage (Ludwigian Age).
		Moorei-beds =		*Aalensis.* *Moorei.*	
	Jurense-zone.	*Dumortieria*-beds.		*Dumortieriæ.*	Toarcian Stage (Harpoceratan Age).
		Dispansum-beds =		*Dispansi.* *Struckmanni.*	
		Striatulum-beds.	=	*Striatuli.*	
		Variabilis-beds.		*Variabilis.*	
	Commune-zone.		=	*Lilli.* *Bifrontis.*	

[1] *Rhynchonella cynocephala*, in a strict sense, is a species of the Aalenian. For dates of *Rhynchonellæ* of the *cynocephala*-group, and their specific distinctions, see my paper on the 'Mid-Cotteswolds' Quart. Journ. Geol. Soc. vol. li (1895) p. 448.

[2] Read for =, 'equal to strata deposited during hemera.' The hemeral names used for stratigraphical purposes would designate the respective faunizones.

VIII. Summary.

The evidence of the fossils found on the flanks of Bredon Hill indicates that the so-called 'Upper Lias' (G 3) of that eminence is equivalent in date to the Cephalopod-Bed, Cotteswold Sands (G 4), and Upper Lias (G 3) of the west flank of the South and Mid-Cotteswolds.

In that case, to the thickness of the Upper Lias (G 3) of Wotton-under-Edge must be added the thickness of G 4 of that locality, to make comparison with G 3 of Bredon. Then the contemporaneous strata at the two places, instead of being 10 feet and 380 feet thick respectively, become approximately 220 and 380 feet thick.

G 3, and G 4 in part, are the strata of the Toarcian Stage. The paper gives details concerning the character and development of these strata in the Cotteswolds, on the Dorset Coast, and in two localities in Normandy.

[For the Discussion, see p. 462.]

37. Two Toarcian Ammonites.

By S. S. Buckman, Esq., F.G.S. (Read May 27th, 1903.)

[Plates XXVII & XXVIII.]

Two ammonites belonging to the family Hildoceratidæ have been found by members of the Cotteswold Naturalists' Field-Club, and have been given to me to name. Both happen to be new forms; and they are of particular interest—one for the geological information which it gives, the other from a biological point of view. The allies of both these species have been figured in my Monograph on the Inferior-Oolite Ammonites (Pal. Soc.)—particularly in the Supplement thereto; but as I have passed the place where they should have been included, I deem it desirable to lay them before the Geological Society. That they are both new species, and that one of them is particularly distinct, shows that in spite of the number of species described, new forms still crop up, and much work yet remains to be accomplished.

Denckmannia bredonensis, sp. nov. (Pl. XXVII, figs. 1–4 *b*.)

Description. — Platy-subleptogyral[1]; subangustumbilicate; whorls bullate (on inner margin), rursi-subflexicostate; septicarinate, parvicarinate; periphery subtabulate; subdensiseptate, with superior lateral lobe broad and subtrilobulate.

Remarks.—Degenerative changes are marked after about 50 mm. diameter. After that the ornament declines, till in another half-whorl costæ and bullæ are nearly lost, expansion of the umbilicus begins, and the subtabulate periphery declines to convexi-fastigate.

Affinity and Distinction.—This species is nearest to *Denckmannia torquata*, S. Buckm.,[2] but the degenerative changes begin at an early age, consequently it soon shows marked decline of ornament, of which that species gives little indication.

The small carina distinguishes it from species of *Haugia*.

History of Figured Specimen.—Found by Surgeon-Major Isaac Newton in a gravel-pit at Overbury (Worcestershire) on the south side of Bredon Hill, when the Cotteswold Naturalists' Field-Club visited that locality. The materials of this gravel-pit are portions of Marlstone, Upper Lias, and Inferior Oolite, derived from Bredon Hill: consequently there is a mixture of species of the Pliensbachian, Toarcian, and Aalenian Stages.

Date of Existence.—Probably hemera *variabilis*, Harpoceratan Age (Toarcian Stage).

Chartronia costigera, sp. nov. (Pl. XXVIII, figs. 1–4.)

Description. — Subplatyleptogyral, sublatumbilicate; rursirectiradiate, costate to pauci- and obscuri-costate; carinate (? septicarinate); subornatilobate, densiseptate.

Remarks. — The specimen has a practically-complete body-chamber, although the actual mouth-border is not preserved. The

[1] See Note on Technical Terms, p. 461.

[2] 'Monogr. Inf. Ool. Amm.' pt. x, Suppl. i, pl. iii, figs. 4–6. (Pal. Soc. vol. lii, 1898.)

length of the body-chamber is just over half a whorl, and this last half-whorl shows a tendency to excentric coiling; there is consequently a somewhat quick expansion of the umbilicus. The ornament is obscure naturally; more so by deficient preservation. In the inner whorls are costæ—the important point as to whether they show any nodi is not determinable. On the last whorl the costæ are few and distant, and tend to become obscure.

The carina, which is small but distinct at the commencement of the last whorl, degenerates to a mere ridge at last. It is presumably hollow, that is a septicarina; but the evidence is not conclusive. It is set on a narrow rounded periphery. The inner margin of the whorls is steeply truncate—more so in the early whorls than later.

Affinity and Distinction.—The present species is quite unlike any other with which I am acquainted. The difficulty is not to separate it, but to say with what other species it can have any genetic connection. My suggestion is this:—It is a platygyral costate degenerative of *Chartronia binodata*[1]; the inner whorls should be the morphic representations of that species: the outer whorls show a costate stage, which is the general rule of decline from a tuberculate stage.

History of Figured Specimen.—Found by Mr. Charles Upton in the *Dispansum*-Bed, a portion of the Cotteswold Cephalopod-Bed, at Buckholt Wood, near Stroud (Gloucestershire). The deposit belongs to the Toarcian Stage.

Date of Existence.—Hemera *dispansi*, Harpoceratan Age.

Biological Note.

Instances of degenerative decline (catagenesis) from the bituberculate to the costate stage are found in the genus *Zurcheria*, of which the different species show the phases of a catagenetic costate stage becoming more and more pronounced, while the bituberculate stage declines to an unituberculate stage, and is in time practically lost.[2]

Similar catagenetic development may be seen in *Paltopleuroceras*. In its acme *Paltopleuroceras* may be said to be trituberculate. The species show stages of decline to simple costate.[3]

Deroceras is another genus which shows catagenetic development from the bituberculate to the costate stage. In many species of this genus the unituberculate stage is the conspicuous feature; in other species catagenesis from the unituberculate to the costate stage is shown. The unituberculate stage, however, is not directly developed from a prior costate stage, but from a preceding bituberculate stage. A specimen from Lyme Regis, which is either *Deroceras armatum* or a close ally thereof (Pl. XXVII, figs. 5 & 6), shows the bituberculate stage, and how the outer tubercle is gaining at the expense of the inner one. Therefore *Deroceras* is derived from a bituberculate form; and its ancestor is either *Microderoceras Birchi*,

[1] 'Monogr. Inf. Ool. Amm.' pt. x, Suppl. i, p. xvi, & pl. i, figs. 11–15. (Pal. Soc. vol. lii, 1898.)

[2] See 'Monogr. Inf. Ool. Amm.' pt. vi, p 294. (Pal. Soc. vol. xlv, 1892.)

[3] See some remarks on these species in 'Descent of *Sonninia* & *Hammatoceras*,' Quart. Journ. Geol. Soc. vol. xlv (1889) pp. 653, 654, under *Pleuroceras*.

or a species which is the morphic equivalent thereof. The inner whorls of the specimen figured are a good morphic representation of *M. Birchi.*

Thus in the phylogenetic history of *Deroceras* would be found the stages smooth, costate, unituberculate, bituberculate, unituberculate; though ontogeny of the usual *D. armatum* may often show no more than smooth, costate, unituberculate—the bituberculate stage having, as it were, been squeezed out by tachygenesis between its pre- and post-unituberculate stages. The smooth, costate, and unituberculate stages which lead up to the full bituberculate development of *Microderoceras Birchi* are well shown in the ontogeny of that species. What two of the stages would have been like as separate species may be learnt from *Ammonites planicosta* and *Am. xiphus*, which show the costate and unituberculate stages respectively. These species cannot be the actual ancestors of *Microderoceras Birchi*, because they are later in date; but they are the morphic equivalents of those ancestors: they show what those ancestors would have been. They are the anagenetic stages.

These anagenetic stages show that, by analogy, there is good reason to suppose that species having similar features will be found leading up to *Chartronia binodata*; or, at any rate, that that species passed through such stages to arrive at its present condition. The cases of degenerative development from bituberculate to costate stages, which have been cited above, indicate that a costate species like this *costigera* may be placed as a catagenetic development from *Chartronia binodata*, and be quite in accordance with the development shown in other series.

Note on Technical Terms.

Concerning the technical terms here used the reader is referred to 'Monogr. Inf. Ool. Amm.' Suppl. i. (Pal. Soc.). But, in order to secure so far as possible an uniform value for these terms, it has been found advisable to use a more definite standard. This is furnished by the radius, that is, the length from the centre to the periphery. This being taken as 100, the percentage of other dimensions may be approximately stated as follows:—

To 17 per cent.	Perstenogyral. Perleptogyral. Perangustumbilicate.
From 17 to 34 per cent....	Stenogyral. Leptogyral. Angustumbilicate.
From 34 to 50 per cent. ...	Substenogyral. Subleptogyral. Subangustumbilicate.
From 50 to 66 per cent....	Subplatygyral. Subpachygyral. Sublatumbilicate.
From 66 to 83 per cent. ...	Platygyral. Pachygyral. Latumbilicate.
From 83 to 100 per cent...	Perplatygyral. Perpachygyral. Perlatumbilicate.

When the dimensions exceed 100 per cent. they may be denoted by affixing the word extreme. Thus certain species might be extreme-pachygyral, with further modifications by per, or sub, when necessary.

There is a certain arbitrariness about this method, as when a slight difference on each side of a dividing-line gives a different designation, while more difference (if falling towards beginning and end of a division) does not, although such may be necessary in specific distinction.

When a dimension falls on the dividing-line, it seems desirable to take the lower denomination as the term.

A proportional triangle, such as that given by Pierre Reynès in the forefront of his Monograph on Ammonites (1879), is suitable for taking the measurements.

EXPLANATION OF PLATES XXVII & XXVIII.

[The specimens are drawn of the natural size.]

Plate XXVII.

Variabilis hemera.

Denckmannia bredonensis, S. Buckman, sp. nov.

Fig. 1. Side view.
2. Peripheral view.
3. Suture-lines.
Figs. 4 *a* & 4 *b*. Radial curves.

The specimen is from the gravel-pit at Overbury (Worcestershire), and is in the collection of Surgeon-Major Isaac Newton.

Armati hemera.

Deroceras sp.

Fig. 5. Side view, showing the bituberculate stage, with the outer row of spines gaining at the expense of the inner. See Biological Note, p. 460.
6. Peripheral view.

The specimen is from the Lias of Lyme Regis [Pliensbachian], and is in my collection. It illustrates the phylogeny of *Deroceras armatum* (Sow.).

Plate XXVIII.

Dispansi hemera.

Chartronia costigera, S. Buckman, sp. nov.

Fig. 1. Side view.
2. Peripheral view.
Figs. 3 *a* & 3 *b*. Suture-lines.
Fig. 4. Radial curve.

This specimen is from the *Dispansum*-Bed of the Cotteswold Cephalopod-Bed (Toarcian) of Buckholt Wood, near Stroud (Gloucestershire), and is in the collection of Mr. Charles Upton.

Discussion (on the two foregoing papers).

The Chairman (Mr. E. T. Newton) remarked that he could say little as to the Bredon-Hill section, except that a map executed 50 years or so ago naturally required considerable modification.

Mr. Hudleston, referring exclusively to the first paper, had very

little doubt that, on the whole, the Author was correct as to what he called the 'Toarcian' of Bredon Hill. The question was one as to whether palæontology or simple lithology was to be our guide in the making of maps. The Author had often insisted on similar points, and it was for the officers of the Geological Survey to reply as best they could. But was not the Author slaying the slain in his present onslaught? He had already proved that the so-called 'Midford Sands' were one thing in one place, and another thing in another. In Gloucestershire the term 'Cotteswold Sands' would be more appropriate. The speaker admitted that it was some years since he had worked at this subject, but as regards the position of his ammonite-zones he had always found the Author correct.

Mr. Whitaker, in regard to Bredon Hill, pointed out that the Survey-work in that area was done 40 or 50 years ago, and a Survey-map did not profess to theorize about fossil-zones, but to constitute a record of lithological facts. No one in those days had heard of 'Toarcian,' or even of 'Midford Sands.' The section which the Author built up from the Survey-map was not one that a surveyor would have drawn. The Midford Sand of one place was not necessarily the Midford Sand of another.

The Rev. J. F. Blake remarked, with reference to the general scheme of ammonite-development propounded by the Author, that what with two series, an ascending and a descending one, and the power assumed of skipping any stage or stages, it was not difficult to fit any ammonite into such a scheme; but the great majority of ammonites had nothing to do with spines—and the theory would make them all immature. In fact they completed their development in many other ways—spines appeared to be only abundant at certain epochs of the Earth's history—and a too exclusive attention to the ammonites of any one such epoch might lead to the idea that spines formed an essential feature in their development. For the rest, the early and late stages of smoothness and lineation were nothing but the natural concomitants of youth and age, as witnessed even in human beings.

With regard to the mapping criticized in the other paper, the speaker yielded to no one in his appreciation of the importance of palæontological zones; but where these were said to be non-coincident with the boundaries of strata of particular lithological character, two courses were open—they might map the zones, and describe the changes of lithology; or they might map the strata, and describe the zones. The latter course he would prefer, as giving more scope for details on the more important subject. But they must remember that the Geological Survey based its justification on the economical importance of its work, and not upon its discrimination of zones, and it was hard that they should be blamed for doing their duty by their paymasters.

Dr. F. A. Bather accepted the previous speaker's comparison of the stages of ammonite-growth and decline to those shown by the human hair, and his statement that they were equally natural. But if so, how could they be of no value in deciphering the history

of an ammonite-race? The stages to which the Author had just drawn attention always followed a regular sequence: a stage might be omitted, or it might never be reached; but those that were observed were always in this sequence. If they could occur anyhow, as suggested by the previous speaker, then, considering the enormous number of ammonite-genera and species, the odds against the sequence always being the same were very heavy indeed. This was a matter of great importance, because if the principles of ammonite-growth and evolution held by the Author and many others were correct, then we were presented with an evolution that appeared to follow regular laws of growth—neither fortuitous, nor governed by contemporaneous cycles of external physical change. This did not appear consistent with evolution by natural selection alone. Further, this origination of new forms, whether species or mutations, was of a very gradual nature, precisely similar to the growth of an individual. This did not appear consistent with a theory of evolution by discontinuous variation alone. Facts such as these were, therefore, opposed to the DeVriesian no less than to the Darwinian scheme.

The AUTHOR, replying to the statements that the Geological-Survey maps were only meant to be lithological charts, of use to agriculturists, said he was afraid that even on these points they had failed; for those purposes the superficial deposits should have been mapped first, instead of last. In solid geology, where Liassic clay passed laterally into sands, it would have been easy to show both contemporaneity and lithic change by the same colour dotted. Now, the maps said that the sands were of later date than the clay, which was incorrect.

In quoting *Ammonites sublævis* as having no spines, Prof. Blake was most unfortunate. It had a spinous young stage, and was a miniature *Blagdeni*. It was one of the best species to illustrate those phenomena of cyclical development to which the Author had drawn attention.

F. H. Michael del. et lith.

Mintern Bros. imp.

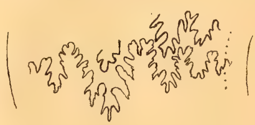
DENCKMANNIA BREDONENSIS, sp. nov.
AND DEROCERAS, sp.

1.

3a.

4.

3b.



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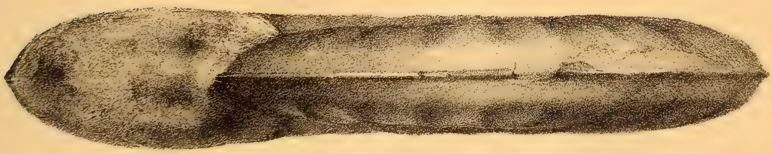

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END OF VOL. LIX.

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C. A. White

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SESSION 1903–1904.

1903.

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„	December	2*—16

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OF

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C. A. White

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THE ASSISTANT-SECRETARY.

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